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EDITORIAL NOTES.

THE fourteenth International Geological Congress will open at Madrid on Monday, 24th May, under the Presidency of H.M. Alfonso XIII, King of Spain. Papers written by intending collaborators should be sent in before 1st April. All particulars may be obtained from the Secretary of the Organizing Committee, 2 Plaza de los Mostenses, Madrid.

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THE Council of the Geological Society of London has made the following awards: Wollaston Medal, Professor H. F. Osborn; Murchison Medal, Professor W. S. Boulton; Lyell Medal, Professor O. T. Jones; Wollaston Fund, Mr. A. L. Leach; Murchison Fund, Mr. W. S. Bisat; Lyell Fund, Mr. F. Raw and Mr. A. F. Hallimond.

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AT the annual general meeting of the same Society, on 19th February, 1926, new officers and members of Council were elected as follows: President, Dr. Bather; Vice-Presidents, Dr. J. W. Evans and Mr. Monckton; Members of Council, Professor Garwood, Dr. Greenly, Dr. Kitchin, Mr. J. Pringle. The retiring President, Dr. Evans, delivered an address on "Regions of Compression". An abstract of this address will be found on a later page.

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THE new officers of the Geologists' Association for the coming year are: President, Mr. A. J. Bull; Vice-President, Mr. H. Dewey (the retiring President); Excursions Secretary, Mr. S. Hall. At the Annual General Meeting on 5th February moieties of the Foulerton Award were presented to Mr. G. E. Dibley and Mr. S. Priest. Professor W. J. Sollas was elected an Honorary Member.

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PROFESSOR O. T. JONES, M.A., D.Sc., of Manchester, has been recommended by the Council for election to the Royal Society.

ORIGINAL ARTICLES.

Note on the Geology of the Bath Springs.

By R. H. Rastall, M.A., Sc.D., M.Inst.M.M., F.G.S.

[This article is reprinted, by kind permission of Dr. A. E. Norburn and the local Committee, from *The Book of Bath*, a handbook prepared for the meeting of the British Medical Association at Bath in July, 1925.]

THE high temperature of the Bath springs, their saline character, and their content of radioactive substances all combine to show that the waters must rise from a great depth. If we take the average temperature of normal spring water at 50° F. and that of the Bath Springs at 120° F., this gives an excess of 70° above the normal. Accepting the usual temperature gradient in England as being 1° F. for every 64 feet of depth, this makes the position of the ultimate source 4,480 feet below the surface. This figure must, however, be regarded as a minimum, since no allowance is here made for cooling on ascent. This is an unknown factor, and sufficient data are not available for a reliable estimate. In any case the depth is unlikely to be less than 5,000 ft. and is probably far greater. This water, then, is obviously something very unlike the ordinary surface springs fed by atmospheric waters circulating in the upper layers of the earth's crust.

In some instances the high temperature of thermal springs has been attributed to heat produced by friction between rock-masses along lines of fracture, but in this case there is little to support that view. In particular, it does not in any way account for the saline character and the radioactivity of the waters; there is little or no indication of any *recent* movement among the rocks of the district; and no earthquakes appear to be recorded in the immediate neighbourhood.

It has been pointed out that analysis of the waters shows the presence of the various saline constituents in proportions differing greatly from those found in sea-water, and it is impossible to attribute the supply to percolation from marine sources. It is necessary to conclude therefore that this and similar thermal springs in other countries are fed by water of deep-seated, or as it may well be called, volcanic origin.

It is clear that the uprise of such waters involves the existence of a pronounced fracture in the earth's crust, communicating with the heated regions below. In the case of the Bath springs it is not difficult to account on geological grounds for the existence of such a fracture.

The city of Bath lies on the eastern margin of the North Somerset or Radstock coalfield, which is itself situated on the northern side of the highly disturbed Mendip region, forming part of the ancient chain of folded rocks that can be traced from the Belgian coalfield under the south of England through South Wales, and further to the extreme west of Ireland. All along this great belt the Carboniferous and older rocks were much broken and disturbed before the deposition of the Triassic and Jurassic systems, which now form most of the surface in Somersetshire. These are flat-lying and almost undisturbed. Again in the western Midlands there is another conspicuous belt of broken rocks of old date, running north and south, forming the Malvern Hills and the May Hill district, and clearly traceable as far as the neighbourhood of Tortworth in Gloucestershire. At this point the ridge of folded rocks appears to split, one branch running just west of Bristol (Clifton Downs, etc.). The other branch bends very slightly to the east, and passes probably almost under the city of Bath, its direction being indicated by small inliers of Carboniferous Limestone at Codrington Court, Wick Rocks, and south-west of Tracy Park. At this point, therefore, the east-and-west lines of folding and fracture of the Mendip system are met by the similar north-and-south lines of the Malvern system. Obviously where two lines of disturbance cross is likely to be a point of extra weakness, and it is highly significant that the Bath waters rise just at this point. This accounts satisfactorily for the rapid rise of the waters through the older rocks from a great depth.

As before mentioned, the city itself lies on rocks belonging to the newer and less disturbed series, chiefly Lias and Oolites. The Lias consists mainly of impervious clays with limestone bands; below it come the Rhaetic beds, also for the most part impervious, and varying considerably in thickness; where these have been penetrated in one or two deep borings they were found to be underlain by red rocks of Triassic age, from which hot water flowed. Evidently then the Rhaetic and Liassic clays seal up the water to some extent, and the exact points of outflow must be determined by some small and more or less accidental fissures which penetrate the clays, probably one or more small faults, which are difficult to detect in an area covered with buildings, and likewise overlain by superficial deposits.

For the purposes of the present note I have had the opportunity of examining some specimens of the material deposited by the springs, kindly supplied by Mr. John Hatton, the Director of the Baths; also by the good offices of Dr. King-Martyn I have been enabled to see a collection of material from the same sources, made many years ago by Mr. J. W. Morris, and described in a locally printed and now scarce pamphlet.[1] Mr. Morris confined his attention largely to the organic contents of the deposits, and especially to the materials found within hazel-nuts. These he identified, quite correctly, as including minerals formed by the thermal waters, especially aragonite and iron sulphides. Some crystals determined by Mr. Morris as celestine appear to be in reality strontianite. The organic remains include some of quite recent origin, both animal and vegetable, while others were almost certainly derived from the underlying Rhaetic strata; it was the presence of these that led Mr. Morris to conclude that "the mineral waters have their origin in some volcanic region to which marine sources have made contribution". The first part of this deduction, as to a volcanic origin, is, as we have seen, quite justified, but the marine contribution was second-hand material which had long formed part of terrestrial rocks. As to the nature and composition of the iron sulphides and other metallic minerals identified by Mr. Morris, something will be said at a later stage. Most of his identifications are quite correct. The hazel-nuts and other recent organic materials do not really throw much light on the problem, though they are of some interest in themselves.

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[1] *Notes on the Results of a Microscopical Examination of the Sands of the King's Bath, and of the Contents of Hazel Nuts collected from the Conduits of the Mineral Baths*, by J. W. Morris, pp. 10, printed by F. Curtis & Sons, Bath, no date.

The whole of the lower part of the city, around the springs, stands on a bed of gravel and sand, deposited by the Avon when running at a higher level than at present. The thermal waters, therefore, pass through these sands, which are referred to in many of the published descriptions of excavations carried on at an early date, as for example, by William Smith in 1810.[1] It is therefore difficult or impossible when dealing with samples obtained from the baths or from the reservoirs below to decide how much of them belongs to this superficial sand-bed, and how much has been brought up from depth by the waters. Mr. Morris in his pamphlet notes that the sand from the springs examined by him is quite different from the modern sands of the Avon, but the excessive leaching by the continuous flow of hot water on the one hand, and on the other hand the addition of material from solution, which has undoubtedly taken place, would naturally bring about an alteration in the appearance of the sands. It is probable, as before noted, that some of the lighter organic material has been brought up from depth; there is likewise a group of minerals clearly formed in place from the thermal waters, as will appear in the subsequent descriptions, but it is very doubtful whether any of the sand grains in the ordinary sense of the term are due to the springs.

The samples supplied to me by Mr. Hatton, which were for the most part collected from the baths about 1912, include three fairly distinct types, as follows:—

(*a*) pale grey coarse-textured and even-grained sand (King's Spring).

(*b*) pale grey fine-grained rather loamy material with much carbon, but little iron (Cross Spring, 1912).

(*c*) bright red ochreous material, very rich in iron.

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[1] See, for example, Townsend, *Geological and Mineralogical Researches* (*The Character of Moses*), Bath, 1824, p. 197. Mr. Townsend then saw the water coming up through the blue clay (Lias) below the sands.

A collection of similar samples can be seen in one of the galleries of the Museum of the Royal Literary and Scientific Institution at Bath.

As the first type is in many ways the most interesting, a short description may be given of the deposit from the King's Spring and of the methods used in its investigation.

When washed in running water a small amount of black organic matter of recent origin floated off, together with a very little grey mud. The sand was then concentrated by panning in the usual way, leaving a fairly large heavy fraction.

Under the microscope the light fraction was found to consist mainly of angular to subangular grains of quartz, of very varying size and some range of colour, e.g., pinkish, greenish, and so on, but many of the grains, and especially the smallest ones, are colourless and often water-clear; the significance of this last fact will be discussed later. A few opaque colourless grains appear to be chert and there is some red jasper and a fair amount of yellow rounded grains of iron oxide

The heavy concentrate was examined in considerable detail. To a horse-shoe magnet it yielded a few grains of magnetite, but most of the black grains were non-magnetic. It was then separated in bromoform of density about 2·9, and the grains that sank, a considerable quantity, were divided into two portions. One portion when boiled with pure concentrated hydrochloric acid yielded a green solution, which contained much iron, but no reaction for copper could be obtained. The other half was mounted for microscopic examination. The most abundant constituent was iron sulphide, mostly as marcasite, though a few crystals of pyrite also appear to be present. The other minerals found were those usual in the heavy fractions of most sands, such as zircon, tourmaline, staurolite, kyanite, and garnet. All these have a rolled and water-worn appearance and are evidently derived from older deposits, but it is quite clear that the marcasite has grown in place, having been deposited in its present form, as aggregates and bunches of small crystals, by the thermal waters.

The second type (*b*), the grey loam, is represented by material collected from the Cross Spring in 1912.

On washing there floated off a good deal of dark-coloured organic matter, apparently of recent origin. There was copious effervescence with dilute acid. After this treatment there was left a dark grey sand containing a good deal of carbonaceous material, apparently distinct from the organic matter previously removed, and suggesting derivation from the Coal Measures. There was also a good deal of white mica. When the coaly matter had been removed the remaining sand was much like that of type (*a*), but of much finer grain.

The sample was then treated as before described. The lighter portion consisted mainly of angular, subangular, and rounded grains of quartz, rounded grains of opaque iron oxide, and not much besides. In the heavy residue from bromoform separation, marcasite, pyrite, haematite, and ilmenite were all abundant, with perhaps a little copper pyrites, though this last is uncertain. The other derived minerals were muscovite, zircon, tourmaline, garnet, rutile, and a very little chloritoid.

Essentially this type differs only from type (*a*) in the size of grain and in the presence of much coaly matter.

The third type of deposit is represented by samples collected from the King's and the Old Royal Springs. In each instance the material is of a bright red or brownish red colour and obviously very ferruginous; it may well be described as ochre. The material from the King's Spring may be briefly described. It is quite soft and crumbly and when gently crushed and washed, a very large amount of brownish red mud is given off. This is evidently very finely divided, but does not appear to be in the colloidal condition, since when shaken up with water in a tall cylinder and allowed to stand, the whole settles and the water becomes quite clear in a few hours. Saline waters are naturally not favourable to colloidal dispersion.

With dilute acid there was copious effervescence, and some of the larger fragments picked out of the sample before the acid treatment are revealed on washing as forming a very soft sandstone with a white chalky-looking cement, which is probably aragonite and not calcite. After much further washing and a second treatment with acid, the final residue was found to be a grey sand, exactly like the non-ferruginous sands before described. This was treated by the same methods, and yielded the same final products after panning and bromoform separation, namely, very abundant marcasite in small globular aggregates of prismatic crystals, together with pyrite, haematite, and ilmenite, with muscovite and the usual transparent heavy minerals, zircon, staurolite, rutile, tourmaline, and others. As rarities chloritoid and probably corundum and anatase are present.

A sample from the Old Royal Spring was almost identical in its constituents, though containing more ochre and less sand. A detailed description need not be given.

The ochreous matter in these samples is evidently deposited by the waters, and is of exactly the same character as the reddish stain that is noticeable in many places in the baths. The iron is no doubt derived originally in part from the decomposition of pyrites in the older rocks below, and in part from the red Triassic rocks through which it passes, as before explained. It is impossible to say how much should be attributed to each source.

With regard to the mineral constituents of these samples, it is necessary to distinguish clearly between the detrital minerals and derived fragments on the one hand, and on the other those deposited from solution in the water. In the first category come all the sand-grains in the ordinary sense of the word, the organic and coaly matter. The second category includes most of the crystalline sulphides and the carbonates, including the crystals found by Mr. Morris inside the nuts. It is not clear whether the ochre was precipitated from soluble compounds by surface oxidation, or was transported in a very finely divided state.

Of the sand grains proper by far the commonest constituent is quartz, and this shows a remarkable range of type and colour. Most of it is colourless, but creamy white and pinkish varieties are common, while occasional grains of quartz with a peculiar green stain due to iron silicate were noted by Townsend in 1824, and by him considered to be derived from the Upper Greensand ; this attribution is doubtless correct. Of most interest are the very numerous grains of perfectly clear and brilliantly transparent quartz, strongly recalling the type of crystals so well known as " Bristol diamonds ". These occur normally in certain curious concretionary nodules in the Dolomitic Conglomerate, which forms part of the Triassic series of the Mendip area. It is possible that some of these grains may have been brought up by the spring waters from this conglomerate, which is known to occur underground in the neighbourhood, but it is more likely that they also belong to the river sands. There are also a good many grains of an opaline or flinty character which may come from the Greensands. The minerals of high density are such as may be found in almost any sand of whatever age and origin, and show no distinctive features.

Of the metallic minerals it is quite clear that the greater part of the iron disulphide has been directly deposited by the mineral waters, in the form of marcasite and not pyrite. It consists of globular aggregates of minute crystals, such masses being quite soft and almost incoherent, a form which could not stand any kind of mechanical transport without breaking up. Much of the haematite appears to have a similar origin, but a few crystals of pyrite and all the magnetite and ilmenite are transported and derived from older rocks.

The calcium carbonate, which occurs both as cement in certain parts of the sands, and as crystals inside the nuts, is mainly aragonite, though a few well-developed dog-tooth crystals of calcite were seen in some of the specimens described by Mr. Morris. It is well known that calcium carbonate is normally deposited from hot solutions as aragonite, as for example at the Karlsbad springs. The presence of strontium compounds is not at all surprising, in view of the abundance of strontium minerals in the Trias at Wickwar and Yate and possibly in other parts of Gloucestershire, and this element has been detected by analysis in solution in the Bath waters.

On the whole the examination of these specimens does not throw much further light on the problem of the origin of the springs, but all the facts observed are entirely consistent with the conclusion reached on other grounds, that the thermal waters rise from a great depth, through Carboniferous and older rocks, and that their character and distribution is to some extent affected by their passage through the Triassic and Liassic strata, underlying the visible surface deposits of the district. The ultimate source of the salts and of the radioactive constituents is to be sought in the heated volcanic zone that must underlie the area at a great depth.

Decapod Crustaceans (*Callianassa*) from the Scotland Beds of Barbados.

By Thomas H. Withers, F.G.S.

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(PLATE IX.)

THE Scotland Beds of Barbados have been considered as a rule to be very unfossiliferous, but Mr. A. Menzies, Geologist to the Union Oil Company, has traced at various places a thin conglomeratic band which contains fossils.

Dr. C. T. Trechmann, F.G.S., has been enabled for two seasons (1923, 1924) to collect from these beds, and has obtained among other fossils, a number of propodites of *Callianassa*, one of the Anomourous Decapods. There are altogether sixteen specimens representing three species. One of these is referable to *C. lacunosa* Rathbun, but the other two cannot be referred to species already known, and they are here described as new.

The age of the Scotland Beds is given as Eocene or Oligocene by Franks and Harrison (1898, *Q.J.G.S.*, vol. liv, p. 550). T. Wayland Vaughan (1919, *Bull.* 103, *U.S. Nat. Mus.*, p. 577) quotes J. W. Gregory (1895, *Q.J.G.S.*, p. 298) as expressing the opinion that "the Scotland 'beds' are of lower Oligocene age". He further states (op. cit., p. 584): "Should the correlation of the Scotland 'beds' with the San Fernando be valid, the Scotland 'beds' are of the same age as the Antigua formation of Antigua, and corroborates the opinion expressed by Gregory." The Scotland Beds and the San Fernando Beds are now included by Wayland Vaughan (1924, *Bull. Geol. Soc. America*, vol. xxxv, table 3) in the Upper Eocene. C. T. Trechmann (1924, Geol. Mag., Vol. LXI, p. 2) states that the fossils "seem to be referable to a considerably higher stage of the Eocene than either the Richmond beds or the Yellow Limestone of Jamaica", and later (1925, Geol. Mag., Vol. LXII, p. 487): "The horizon of the fauna seems to be high in the Middle Eocene or rather low in the Upper Eocene (Lutetian-Auversian-Bartonian)."

One of the present Decapods appears to be the same as *Callianassa lacunosa* Rathbun, occurring in the Culebra formation (Middle and Upper Oligocene) of Panama, and another species, *C. menziesi*, is closely related to the Culebra species *C. elongata* Rathbun. If the Culebra formation is Oligocene, then the Decapod Crustacea of the Scotland Beds indicate a younger age than do the Mollusca.

Callianassa menziesi sp.n. (Pl. IX, Figs. 1, 2.)

Diagnosis.—A *Callianassa* with the hand much elongated, the upper and lower margins strongly convergent, the proximal margin moderately oblique, much shorter than the upper margin, and forming with it less than a right angle.

Distribution.—(?) Oligocene (Scotland Beds): Cane Garden, Spa Estate, Barbados.

Collection.—Collected by Dr. C. T. Trechmann, F.G.S., and presented to the Geological Department of the British Museum, registered In. 25772.

Holotype.—The unique right propodite. (Figs. 1, 2.)

Description.—Hand elongate (length of upper margin, 12·7 mm., lower margin, 11·6 mm.; height, greatest 9·3 mm., smallest 7·5 mm.), the upper and lower margins strongly convergent; upper margin almost straight, slightly convex proximally, with the proximal angle slightly rounded off, and with a sharp carina extending its whole length, the proximal third slightly overhanging the inner surface; lower margin slightly sinuous, with the edge sharp and evidently originally serrated; proximal margin moderately oblique, much shorter than the upper margin. Outer surface regularly convex longitudinally, apparently without any granules; inner surface generally flat, slightly humped transversely down the middle, and with a deep and strongly curved sulcus near to the articulation with the carpus. Immovable finger slender, directed downwards, with a relatively strong prehensile tooth about halfway from the base.

Remarks.—This species appears to come nearest to *Callianassa elongata* Rathbun (1918, *Bull.* 103, *U.S. Nat. Mus.*, p. 139, pl. lx, figs. 4–6) from the Oligocene (lower part of upper half of Culebra formation) of the Panama Canal zone. It differs much from *C. elongata*, however, in its proportions, for it is more elongate, the upper and lower margins are more convergent, the proximal margin is oblique, is much shorter than the upper margin, and forms with it a right angle, and the lower margin is less sinuous.

Callianassa lacunosa Rathbun. (Pl. IX, Figs. 3, 4.)

1918. *Callianassa lacunosa* Rathbun, *Bull.* 103, *U.S. Nat. Mus.*, p. 138, pl. lix, figs. 6–11.

Diagnosis.—A *Callianassa* with the proximal margin of the hand very oblique, upper margin almost straight and parallel with the lower margin, which has a smooth edge. Outer surface with a strong blunt ridge which extends from the top of the immovable finger on to the hand for about one-third of its length; eight comparatively large and much elongated sockets are just below the upper margin on the inner surface.

Distribution.—(?) Oligocene (Scotland Beds): Cane Garden, Spa Estate, Barbados.

Collection.—Collected by Dr. C. T. Trechmann, F.G.S., and presented to the Geological Department of the British Museum, registered In. 25773.

Material.—The imperfect left propodite. (Figs. 3, 4.)

Description.—Hand rhomboidal (length of upper margin 7·4 mm., length at level with the interdigital sinus 7·4 mm., height 7 mm., thickness 3·3 mm.), upper and lower margins sub-parallel, thin sharp-edged, smooth, the upper margin almost straight, lower margin almost straight, proximal margin very oblique. On the outer surface a row of minute sockets is possibly present below the upper marginal rim, and there are some signs of tuberculation, but only two sockets can be made out above the lower marginal rim. A prominent blunt ridge extends from the top of the immovable finger until it reaches a point level with the top of the interdigital sinus, and extends on to the hand to about one-third of its length. A similar ridge is seen on the inner surface, but it is blunter and situated distinctly lower. On the inner surface, just below the thin upper marginal rim, there is a row of eight sockets, the openings being comparatively large, much elongated, and obliquely inclined distally. Immediately above the lower marginal rim, almost at its edge, there is a row of small circular sockets, possibly twelve, but since the edge is broken in places their actual number cannot be made out. There are a few scattered sockets on the lower half of the outer and inner surfaces of the hand.

Remarks.—This specimen so closely resembles the holotype of *C. lacunosa* Rathbun, from the Oligocene (lower part of Culebra formation) of the Panama Canal zone, that it must be referred to that species. While it agrees in most of its characters with *C. lacunosa*, still the eight elongate sockets below the upper margin on the inner surface are of comparatively greater length.

Callianassa pustulata sp.n. (Pl. IX, Figs. 5–9.)

Diagnosis.—A *Callianassa* with the upper and lower margins of the hand parallel, a slight spine at the top of the interdigital sinus, two oblique rows of sockets extending across the outer surface below the middle, and two parallel rows of small circular sockets on the inner surface below the upper margin. Patches of granules becoming coarser distalwards, on the lower half of both inner and outer surfaces.

Distribution.—(?) Oligocene (Scotland Beds): Cane Garden, Spa Estate, Barbados.

Collection.—Collected by Dr. C. T. Trechmann, F.G.S. Eleven specimens are in the Geological Department of the British Museum, registered In. 25774–In. 25784, and three specimens have been presented by Dr. Trechmann to the U.S. National Museum.

Holotype.—A right propodite (Figs. 5, 6), Brit. Mus., In. 25774.

Material.—Fourteen examples of the propodite (six right, and eight left).

Description.—Hand quadrate, slightly longer than high (length of holotype 13·8 mm., height 12 mm.). Upper margin slightly arched, somewhat broadly rounded, with a sharp ridge, more prominent proximally, extending along its inner edge. Lower margin straight to slightly sinuous, sharp-edged, with the outer edge forming a slight raised rim, and the inner edge serrated, with a single row of probably twenty small sockets. Immediately above the rim of the lower margin there is a single row of probably twelve small circular sockets, and on the inner face a dark-coloured band extends along the lower margin. At the upper margin on the outer face there is a single row of minute and widely spaced sockets, probably numbering seven or eight in all, and on the inner face there are two parallel rows of similar sockets, those of the bottom row tending to alternate with those above. A small spine is present in the interdigital sinus, close up against the base of the articulation with the dactylus ; this spine is followed by three or four small equi-distant tubercles extending in line on to the upper margin of the immovable finger.

On the outer surface two parallel and oblique rows of from six to seven sockets extend from the base of the articulation with the carpus to just above the interdigital sinus ; an irregular patch of widely spaced granules, becoming coarser as they reach the interdigital sinus, extends along the lower half of the hand. On the inner surface there is a similar patch of granules, but these commence nearer to the proximal margin.

Immovable finger slender, and its upper outer margin forms a sharp ridge which apparently dies out at the interdigital sinus ; a similar ridge is seen on the inner surface, and this extends on to the hand beyond the interdigital sinus and in line with the lower part of the sinus.

Remarks.—This species has no very striking characters, but it may be compared with *Callianassa spinulosa* Rathbun (1918, *Bull.* 103, *U.S. Nat. Mus.*, p. 143, pl. lxi, figs. 6–9), from the Oligocene (lower part of upper half of Culebra formation) of the Panama Canal zone. It differs mainly in the presence of two parallel rows of sockets near the upper margin on the inner face, and the two oblique rows of sockets extending across the outer face of the hand below the middle on the lower half of the outer and inner surfaces, and in being more extensively ornamented with granules.

I wish to thank Miss Mary J. Rathbun, of the U.S. National Museum, for kindly comparing at my request the specimens described in this paper with the types of her mentioned species from the Panama region.

EXPLANATION OF PLATE IX.

Callianassa menziesi sp.n.

Fig. 1.—Right propodite. Outer view. Holotype. Brit. Mus., In. 25772. × 2 diam.

Fig. 2.—Inner view of same.

Callianassa lacunosa Rathbun.

Fig. 3.—Left propodite. Outer view. Brit. Mus., In. 25773. × 4 diam.
Fig. 4.—Inner view of same.

Callianassa pustulata sp.n.

Fig. 5.—Right propodite. Outer view. Holotype. Brit. Mus., In. 25774. × 2 diam.
Fig. 6.—Inner view of same.
Fig. 7.—Right propodite. Inner view. Brit. Mus., In. 25775. × 3 diam.
Fig. 8.—Right propodite. Outer view of small example. Brit. Mus., In. 25776. × 4 diam.
Fig. 9.—Inner view of same.

The Magmatic Origin of the Sudbury Nickel Ores.

By A. P. Coleman, Royal Ontario Museum, Toronto, Canada.

PROFESSOR GREGORY, in a very interesting paper published in the *Transactions of the Faraday Society*,[1] has advanced various arguments against the theory of the magmatic origin of the Sudbury nickel deposits and has quoted several authorities as opposing that theory. His brief account of the subject presents, unintentionally of course, only one side of the controversy in regard to those ores, and lest the deservedly great authority of his opinion should seem to settle the question, I wish to place before English geologists an outline of the arguments on the other side.

Like other opponents of the magmatic theory he sets out with the order of succession of the minerals in the ores of the working mines and considers that this arrangement can be accounted for only by aqueous action. He overlooks the broad field relationships which have compelled all the geologists who have mapped the region to adopt the magmatic theory; and in particular he gives no consideration to the crucial question of the pyrrhotite-norites. At all the mines the ore bodies adjoin and pass into rock thickly dotted with blebs of ore, and this norite with disseminated ore occurs on an enormous scale. Near the greatest of the mines, the Creighton, there is a belt of pyrrhotite-norite 600 yards wide and three-quarters of a mile long containing nearly half a per cent of nickel,[2] and spots of ore more sparsely scattered occur in the norite for half a mile further from the mine. The depth to which this ore-bearing rock extends is not known; but it is certain that the rock charged with sulphides contains far more ore than the mine itself. It is evident that any theory proposed to account for the ore bodies must also account for the disseminated ores. This pyrrhotite-norite, containing more than half of the nickel ore of the region, is never referred to by the opponents of the magmatic theory, but cannot be overlooked by the field geologist, who finds in it the solution of the whole problem.

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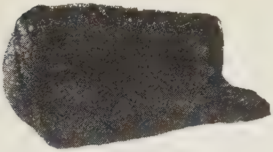
[1] *Trans. Faraday Soc.*, No. 60, vol. xx, pt. iii, 1925, pp. 449–58.
[2] Wandke and Hoffman in *Econ. Geol.*, vol. xix, 1924, p. 200.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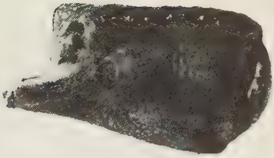
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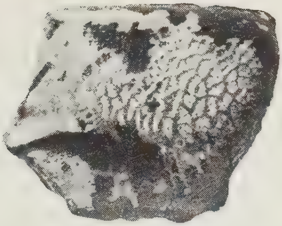
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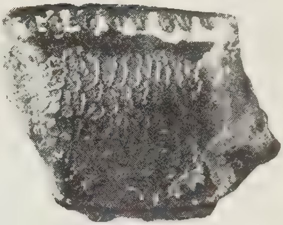
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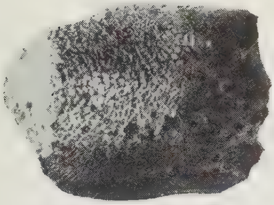
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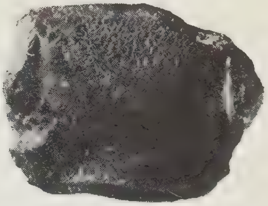
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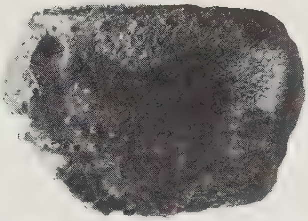
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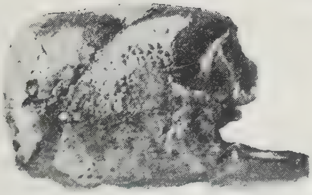
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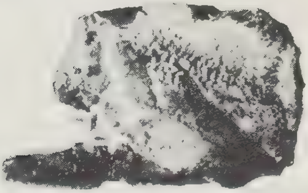
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H. G. Herring, photo.

West Indian (Barbados) Tertiary Decapods.

[*To face p. 108.*

In many places the pyrrhotite-norite is greatly weathered, but fortunately parts of the rock near the two greatest mines of the district, the Creighton and the Murray, have proved to be perfectly fresh, even the highly susceptible mineral, hypersthene, being quite unchanged.

This fresh rock was carefully studied in the field and in thin sections during the preparation of the map of the nickel region, and it was proved conclusively that the blebs of ore are completely enclosed in rock with no fissures or openings through which water could circulate. The sulphides are sharply bounded by unchanged silicates and are evidently as truly a part of the rock as the magnetite or apatite found in the sections. These completely enclosed portions of sulphides were unmistakably parts of the cooling magma. In some places they occur only once or twice in a cubic yard of norite, with no hint of an opening through which water could percolate.

Now these small masses of sulphide consist of pyrrhotite, chalcopyrite, and pentlandite, and have exactly the composition and appearance of the ores in the mines. The relative proportions of nickel and copper are the same as in the ores of the mines. The largest known nickel deposit, containing 45,000,000 tons, as shown by diamond drilling, is the Frood or No. 3 mine, where the bulk of the ore is pyrrhotite-norite of the sort described, though slightly weathered, the pyroxenes having been changed to hornblende.

It has just been shown that the greater part of the ore of the region can be accounted for only by magmatic segregation; can it be doubted that the smaller portion occurring in the mines has originated in the same way, though it has been somewhat rearranged by hydrothermal processes? It is this rearrangement which has attracted the attention of the hydrothermalists and they have neglected to inquire as to the original source of the ores. It must be remembered that every ore body is accompanied by pyrrhotite-norite; though sometimes the rock is almost unrecognizably weathered in offset deposits. On the other hand, the country rock may be any of the older sediments or eruptives of the region without influencing the ores in the slightest. Why should all the ore bodies be at or near the base of a single sheet of basic eruptive and be accompanied by pyrrhotite-norite, often on an enormous scale, and why should all the ores have the same monotonous minerals, pyrrhotite, chalcopyrite, and pentlandite, unless they were derived from the norite itself? Ore bodies have never been found away from the norite or its offsets, which immediately suggests that the norite brought the ores.

It will be of interest to discuss briefly the validity of the arguments brought forward by Professor Gregory.

After referring to Professor Vogt's proof that pyrrhotite remains in a norite magma after some of the silicates have crystallized, he goes on to say, " This sequence agrees with that observed in the Sudbury norite; but it is the opposite to that assumed by the segregation theory. For if the nickel-pyrrhotite is the last constituent to solidify the agency assumed to segregate it on the base of the norite sheet would not be operative. The pyrrhotite would be scattered through the solid silicates and not formed as heavy grains in a lighter liquid, through which it would sink."

As shown above, and also as illustrated by Professor Vogt's experiments on silicate-sulphide melts, the greater part of the ore is actually enclosed in the lower portions of the norite, like shots of matte in slag. Only a smaller part made its way to the bottom to form ore bodies before the magma became too viscid to permit the sulphides to escape. The dilemma he suggests, instead of opposing the segregation theory, strongly supports it.

Dr. Harker is quoted as denying the transition from norite to micropegmatite, but if he should study the suites of specimens collected by Professor T. L. Walker and myself, along with our thin sections showing every transition between the two extremes, I feel sure that so excellent a petrographer would admit the proof of magmatic segregation of the nickel-bearing eruptive sheet.

Professor Gregory's statement that "even the view that the nickel ores occur in the norite, which is the essence and motive of the segregation theory, has been largely refuted by later work", is no doubt founded on Mr. Knight's conclusion that "the commercial ore bodies are found almost wholly in the rocks adjacent to the norite—not in the norite".

Now this is exactly what the segregation theory demands. As long as the magma was fluid enough to permit the melted sulphides to pass through they poured into all the fissures beneath, and in the faulting which accompanied the coming in and adjustment of the nickel-eruptive and which is clearly to be seen at almost all the mines, the fluid ore came under pressure of the shifting blocks and was forced into every open channel and also into brecciated zones where it congealed between the rock fragments.

This extension of the segregation theory was suggested by Dr. Howe[1] and Dr. Bateman,[2] who have devoted much time to a study of the Sudbury ore deposits.

Professor Gregory quotes Mr. Knight as declaring that the one conclusion which may be accepted as a "certainty is that the sulphides were introduced after the norite-micropegmatite. This is proved beyond a doubt": and apparently he approves of this statement. How entirely inapplicable this is to the Sudbury nickel region is sufficiently proved by the fact that the greatest of all the deposits, the Frood or No. 3 property, consists mainly of pyrrhotite-norite which cannot possibly be explained otherwise than by magmatic segregation, as shown earlier in the present paper.

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[1] Howe, *Econ. Geology*, vol. ix, 1914, pp. 503, etc.

[2] Bateman, *Econ. Geology*, vol. xii, 1917, pp. 391, etc.

The opponents of the segregation theory have been so engrossed with the evidences of hydrothermal action in giving the final form to some of the great ore deposits that they have entirely overlooked the question of the source of the ore and of the enormous amount of sulphides having the same composition as the ore which is distributed as small blebs through cubic miles of pyrrhotite-norite. They have been led astray by the lack of a knowledge of the field relationships. They ignore the disseminated ores, which include much the larger part of the nickel-bearing sulphides and which give the clue to the origin of the ore bodies of the mines themselves.

The theory of the magmatic segregation of a very minute percentage of sulphides out of a vast sheet of eruptive rock slowly cooling under a thick blanket of sediments gives a reasonable starting-point for the whole series of phenomena observed. The heavier materials, norite and ore, tended to settle to the bottom, leaving the lighter granitic portion to cool near the top of the sheet, stoping and absorbing some of the overlying sediments. The sulphides were mostly trapped as tiny blebs in the lower part of the crystallizing norite magma ; but a smaller portion escaped into pools in the depressions below the norite. A great amount of settling and faulting took place in the enclosing rocks, which were often shattered and fissured, as can be seen near the great mines ; and in this process some of the liquid sulphide came under pressure and was forced into fissured and brecciated zones. As the final cooling proceeded hot magmatic waters or vapours acted to some extent upon the minerals of the rocks and the ores themselves.

The process just outlined gives a reasonable explanation of all the phenomena, while the hydrothermal theory leaves out of account most of the significant features found in the region as a whole.

It is perhaps worthy of mention that the writer, when instructed by the Bureau of Mines of Ontario to prepare a map of the nickel ranges, was opposed to the idea of a magmatic origin of the ore deposits ; but as the field work progressed he and his assistants were compelled to accept the theory. It was largely the wide extent of the pyrrhotite-norites and their relationships to the ore bodies which made the hydrothermal theory seem impossible ; none of the supporters of that theory have attempted to account for this most important feature of the geology.

The map prepared during four summers of field work is admitted to be fairly correct and has not been superseded by any other map, and it is really the embodiment of the magmatic theory. It enabled the prediction to be made that ore deposits would be found under a wide stretch of drift toward the east end of the basin. Some years later, by diamond drilling, a body of ore 7,500 feet long and passing upward into pyrrhotite-norite was found there.[1] Could any supporter of the hydrothermal theory have predicted such a thing ?

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[1] H. M. Roberts and R. D. Longyear, " Genesis of the Sudbury Nickel-Copper Ores as Indicated by Recent Explorations " : *Trans. Am. Inst. Mining Engineers*, 1918.

May one suggest that hydrothermalists should consider carefully the results of the field geologists, particularly as to the relationships of the blebs of ore in the pyrrhotite-norites which contain far the larger part of the nickel sulphides of the region, before they come to conclusions derived from the succession of minerals at the mines. Everyone admits that circulating hot water has modified them, especially in offset deposits, but no hot waters could have distributed the little particles of sulphides through cubic miles of pyrrhotite-norite, sometimes absolutely fresh and without shearing or fissures. The origin of this part of the ore can be accounted for only by magmatic segregation; and, if that is so, what is the probability that the rest of the ore originated in some other way?

The Larger Foraminifera of the Upper Ranikot Series (Lower Eocene) of Sind, India.

By W. L. F. Nuttall, D.F.C., M.A., F.G.S., Sedgwick Museum, Cambridge.

(PLATES X AND XI.)

Introduction.

THE following article includes a description of the larger Foraminifera of the Upper Ranikot Series of Sind in Western India. The specimens examined consist of a collection made by Mr. D. Dale Condit and by myself in the winter of 1923, as well as material kindly loaned by the Indian Geological Survey. I wish to thank the directors of the Whitehall Petroleum Corporation for permitting me to make use of the specimens collected during a geological reconnaissance undertaken on their behalf. Of the specimens figured those loaned by the Survey have been returned to Calcutta, and the remainder placed in the Sedgwick Museum, Cambridge.

Classification of the Upper Ranikot Series.

In 1876 Blanford (2)[1] used the term "Ranikot Series" for the lowermost Eocene rocks of Sind and in 1879 (3) described the geology of the region in which the beds outcrop. The Upper Ranikot consists of highly fossiliferous marine limestones and shales. The fauna of these beds has been the subject of several palaeontological studies. In 1853 Messrs. d'Archiac and Haime described numerous fossils from the formation, but their specimens were not separated from those derived from the Upper Cretaceous and overlying Tertiary strata. In 1880 Duncan described the corals. In 1883 Duncan and Sladen (11) described the Echinoids and in 1909 Cossman and Pissaro (5) the Cephalopods and Gasteropods.

The most recent account of the stratigraphy of the Upper Ranikot

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[1] Figures in parentheses refer to Bibliography at end of article.

Series is that of Vredenburg published in 1909 (18). He estimated the maximum thickness of the formation as 800 feet, and recognized the following zones :—

Zone 4.	(Uppermost zone)	with *Nummulites planulatus.*
Zone 3.		with *Assilina miscella.*
Zone 2.		with *Operculina* sp.
Zone 1.	(Lowermost zone)	with *Calytrophorus indicus.*

The examination of the Foraminifera has revealed that the identification of Vredenburg's third zone fossil was incorrect. *Nummulites miscella,* described originally thus by d'Archiac and Haime, is not an *Assilina,* but is referable to the genus *Siderolites* (see Douvillé 7*a*). The Indian Geological Survey have sent me specimens named by Vredenburg *Assilina miscella.* The fossil to which he assigned this name is not *Siderolites miscella* (d'Archiac and Haime) but an *Assilina,* which I have described below as *Assilina ranikoti* sp. nov. For Vredenburg's third zone fossil it will therefore be necessary to substitute *A. ranikoti* in the place of *A. miscella.* The true *Siderolites miscella* is also present in the Upper Ranikot Series. I have found it in a rock sample collected by the Indian Survey from the horizon of Vredenburg's zone 4. In addition there are numerous specimens of this species in my own collection from approximately the same level.

Regarding the other Foraminifera *Nummulites planulatus,* which was recorded by Vredenburg, was never figured or described from India. *Operculina canalifera* and *O. hardiei* were figured and described by d'Archiac and Haime. I have described below a new form (*D. conditi* sp. nov.) of the peculiar genus *Dictyoconoides* of which only one other species is known. The other species that occur are *Nummulites* aff. *guettardi, Alveolina oblonga, Flosculina globosa* and one indeterminate species each of the genera *Operculina* and *Discocyclina.*

THE AGE OF THE UPPER RANIKOT SERIES.

In 1909 Cossman and Pissaro described the Gasteropods and Cephalopods of the Upper Ranikot and found all the species different to European forms. They classified the formation as Ypresian (5). Of the larger Foraminifera that occur in the Upper Ranikot *Nummulites planulatus* is characteristic of the European Ypresian. *Nummulites guettardi* (as defined below) is recorded from the Lower Eocene of Southern France, *Alveolina oblonga* and *Flosculina globosa* occur in the Middle and Lower Eocene of Europe. Forms closely related to *Operculina canalifera* are found in the European Lower Eocene and Lutetian. In 1916 Professor H. Douvillé (7) described the fauna of the Upper Cretaceous and Lower Tertiary of Central Tibet. He figures *O. canalifera* and *Siderolites miscella* from beds classified then as Danian, which strata he has since referred to the base of the Lower Eocene (9). He also pointed out that *Siderolites miscella* strongly resembled the European Upper Cretaceous *S. vidali*, Douvillé (described in *Bull. Soc. Géol. France*, ser. 4, vol. vi, p. 598–9, pl. xviii, fig. 9).

It would appear that in Western India there is a more gradual transition from the Eocene to the Cretaceous than found in Europe. The Upper Ranikot appears to pass down conformably into the estuarine Lower Ranikot, which consists of a maximum of 1,500 feet of nearly unfossiliferous sandstones and shales. Vredenburg has described these beds, which are well exposed in the Laki Range. The Lower Ranikot rests on a single flow of trap considered to belong to the Deccan period of vulcanicity, which overlies the Danian "*Cardita beaumonti* Beds". The formation immediately overlying the Upper Ranikot in Sind is the Laki Series, which I have recently classified as Lower Eocene (16) (approximately equivalent to the European Ypresian and Thanetian, *sensu lato*). I consider the Upper Ranikot Series as belonging to the basal part of the Lower Eocene (beds possibly equivalent to part of the Thanetian and Montian of Europe).

DESCRIPTION OF THE FORAMINIFERA.

Genus NUMMULITES Lamarck.

Nummulites planulatus (Lam.). (Pl. X, Figs. 1–2. Text-fig. 1.)

1804. *Lenticulites planulata* Lam. (13).
1853. *Nummulites planulata* D'Orbigny, d'Arch. & Haime (1*a*)
1883. *Nummulites planulata* (Lam.) Harpe (12).
1911. *Nummulites planulatus* (Lam.) Boussac, *pars*, Form B only (4).
1919. *Nummulites planulatus* (Lam.) Douvillé (8*a*).

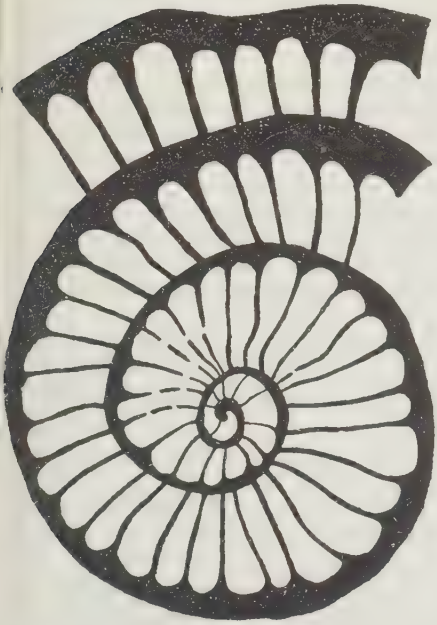
Description.—The Indian representatives of the microspheric form of this species have an average diameter of 11·2 mm. and average thickness 2·6 mm. In the case of ten typical specimens the maximum observed diameter was 14·7 mm., and the maximum thickness 2·8 mm. The average ratio of diameter to thickness is 4·4 to 1. In an equatorial section (Text-fig. 1) the chambers are about three times as long as wide, the septa slender and only slightly curved. In a radius of 6 mm. there are from 4 to 6 whorls.

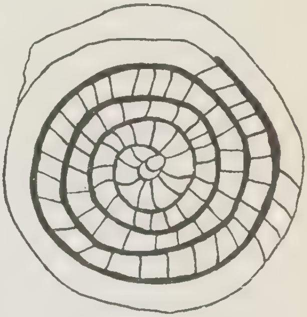
In one quadrant of the 2nd whorl there are 6 to 7 septa
" " " 3rd " " 7 " 9 "
" " " 4th " " 9 " 10 "
" " " 5th " " 13 " 14 "

The septal filaments are nearly straight radiate to well curved, and bear narrow transverse trabecules, which are only visible in a few particularly well preserved specimens. A marginal cord is sometimes present.

Remarks.—I have compared the Indian specimens with *N. planulatus* from the Ypresian of Cuise La Motte, and in the European forms the septal filaments are generally more flexed. Also in the Indian specimens there are less whorls in a given radius than is typical with the European forms, de la Harpe mentioning eight to nine whorls in a radius of 5 mm. for the latter. These differences are not considered sufficient to warrant the establishment of a new species or variety for the Indian specimens, which may be considered a local "race". I have not found the megalospheric form.

Occurrence.—(*a*) North by east of Petiani; N.W. of Kotri, coll. Fedden in 1875–6: I.G.S. No. G. 280/135. (*b*) The lower terrace at Jherruck; coll. Blanford and Fedden, Dec., 1875; I.G.S. No. G. 280/124*a* and No. K. 6/986; also C. and N.[1]





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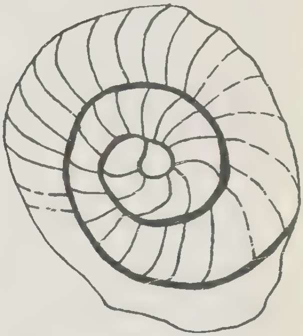

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Fig. 1.—*Nummulites planulatus* (Lam.). × 12. Equatorial section, drawn by camera lucida. Jherruck. I.G.S., G. 280/124a.

Fig. 2.—*Nummulites guettardi* (d'Arch.). × 12. Equatorial section. 5½ miles S.E. of Meting, coll. C. and N.

Fig. 3.—*Siderolites miscella* (d'Arch. and Haime). × 12. Equatorial section. S.W. of Hilaia Trig. Station, coll. C. and N.

Nummulites aff. *guettardi* d'Arch. (Pl. X, Figs. 3–4. Text-fig. 2.)

1853. *Nummulites guettardi* d'Arch., d'Arch. & Haime (1*b*).
1919. ,, ,, d'Arch., Douvillé (8*b*).
1924. ,, ,, d'Arch., Douvillé (10).

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[1] C. and N. collected by D. D. Condit and W. L. F. Nuttall.

The European species, *N. guettardi*, is a small radiate Nummulite, which until recently has always been classified as the megalospheric form of *N. atacicus* Leymerie. Professor H. Douvillé has explained why this is incorrect, and has proposed the name *N. subatacicus* for the megalospheric form of *N. atacicus*. The couple, *N. atacicus-subatacicus* occurs in the Laki and Kirthar Series of Western India (16*d*), while a form closely resembling *N. guettardi* appears to be restricted to the Upper Ranikot Series. *N. globulus* Leymerie, which is the microspheric associated form of *N. guettardi*, has not been found in Sind. Its absence renders it very difficult to make a definite specific determination for the megalospheric form, as there are several species of small megalospheric radiate *Nummulites*, which differ little one from the other.

For ten typical specimens from Sind the average diameter of the test is about 3 mm., the maximum observed diameter being 5 mm. The average thickness is 2 mm., the maximum observed thickness being 2·5 mm. The border is sharp and the septal filaments nearly straight. Most of the specimens examined are devoid of a median pustule, but in a few cases one was observed to be present, and in these instances the forms approach *N. mamilla* (Fichtel and Moll) (according to Douvillé's recent classification 10). In an equatorial section (Text-fig. 2) it is seen that the primordial chamber is bicellular, the whorl laminae fairly thick, the whorls set close together, and the septa nearly straight. In a radius of 1·5 to 2 mm. there are usually 5 whorls.

Occurrence.—(*a*) The lower limestone terrace, Jherruck, coll. Fedden, I.G.S., No. G. 280/124*a*; also C. and N. (*b*) S.W. of Hilaia Trig. Station, S.W. of Jherruck, coll. C. and N. (*c*) 5½ miles S.E. of Meting, coll. C. and N.

Genus SIDEROLITES Lamarck.

Siderolites miscella (d'Arch. & Haime). (Pl. X, Figs. 5–6. Text-fig. 3.)

1853. *Nummulites miscella* d'Arch. & Haime (1*c*).
1906. non *Assilina miscella* (d'Arch. & Haime) Vredenburg (17).
1909. non *Assilina miscella* (d'Arch. & Haime) Vredenburg (18).
1916. *Siderolites miscella* (d'Arch. & Haime) Douvillé (7*a*).

The details of the external appearance of this species have been well described by d'Archiac and more recently by Douvillé. The internal structure of the median chamber layer is shown in Text-fig. 3. The form is megalospheric, the diameter of the unicellular primordial chamber being about 0·3 mm. In a radius of 1·5 mm. there are two or three whorls and in a radius of 2 mm. three whorls. The whorl laminae are narrow, the septa slender and gently curved. As regards size for ten typical specimens the average diameter of the test is 3·1 mm., the maximum diameter observed being 3·7 mm. The average thickness is 1·6 mm., the maximum observed thickness 2·0 mm. The average ratio to thickness of diameter is 1 to 2. Vredenburg ascribed to this species *Assilina ranikoti*, which is described below.

Occurrence.—(*a*) N.E. of Petiani, S.W. of Kotri, I.G.S. No. G. 280/135. (*b*) S.W. of Hilaia Trig. Station, S.W. of Jherruck, coll. C. and N. (*c*) 5½ miles S.E. of Meting, coll. C. and N. (*d*) The lower terrace forming limestone, Jherruck, coll C. and N.

Genus Assilina d'Orbigny.

Assilina ranikoti sp. nov. (Pl. X, Figs. 7–11.)

1906. *Assilina miscella* (d'Arch. & Haime) Vredenburg (17).
1909. *Assilina miscella* (d'Arch. & Haime) Vredenburg (18).

Description.—Test thin, lenticular to globular, with a sharp border. Average diameter 2·7 mm., the diameter observed in ten typical specimens varying from 1·8 to 3·0 mm. The average thickness is 1·1 mm., the thickness varying from 2·0 to 0·7 mm. Externally the ornamentation consists of prominent granules, which are variable in size and number. Commonly near the centre of the test in adult forms there are from 10 to 20 large smooth granules as in Figs. 7 and 8. The last whorl is frequently devoid of granules, and the ribs, which stand out on the outer surface, correspond with the septa of the internal structure. In some specimens where the granules are small, as in Fig. 9, it may be seen that the latter are arranged along the ribs, this being best seen in the young forms.

Internally the structure of the median chamber layer is shown in Fig. 11. There are four whorls in a radius of 1·5 to 2 mm. The form is microspheric, the whorl laminae fairly thick, and the septa gently curved.

Remarks.—The Indian Survey have sent me specimens of this fossil from Jherruck named by Vredenburg *Assilina miscella.* It is difficult to understand how he confused this fossil with *Siderolites miscella* described above. D'Archiac's original description of *Nummulites miscella* is precise, but his figures are poor, and it would appear that Vredenburg never noticed any specimens of this last fossil in the palaeontological collections which he examined. The foraminifer which he named *Assilina miscella* and used as a zone-fossil for his third zone is *Assilina ranikoti*, described above.

Occurrence.—(*a*) N.E of Petiani, N.W. of Kotri, coll. by Fedden; I.G.S. No. G. 280/135. (*b*) The lower terrace, Jherruck; I.G.S. No. G. 280/124*a*. (*c*) 8 miles N.W. of Kotri, coll. C. and N. (*d*) 5½ miles S.E. of Meting, coll. C. and N. (*e*) S.W. of Hilaia Trig. Station, S.W. of Jherruck, coll. C. and N.

Genus Operculina d'Orbigny.

Operculina canalifera d'Arch. (Pl. XI, Figs. 1–2.)

1853. *Operculina canalifera* d'Arch., d'Arch & Haime (1*d*)
1916. *Operculina canalifera* d'Arch., Douvillé (7*b*).

This species was recorded by d'Archiac and Haime from " calcaire jaunâtre de la Chaine d'Hala ". They gave a good description and their figures illustrate well the variations in ornamentation. In most specimens the marginal cord is pronounced and the septa visible externally (as in Fig. 1), but in a few cases the exterior is nearly smooth with only a slightly raised marginal cord corresponding with the whorl lamina (see Fig 2). At the centre of the shell there are always a few small granules. In equatorial section the septa are curved, closely set, and variable in number. The diameter of thirty specimens I have examined varies from 10 to 21 mm., the average thickness being 1·5 mm. There are usually three and occasionally four whorls, which are not set as close together as in *O. ammonea* Leymerie (14*a*) or *Assilina praespira* Douvillé (6)

Occurrence.—(*a*) The lower terrace, Jherruck, I.G.S. No. G. 280/124*a* and K. 6/986. (*b*) S.W. of Hilaia Trig. Station, S.W. of Jherruck, coll. C. and N.

Operculina hardiei d'Arch. & Haime. (Pl. XI, Figs. 3–4.)

1853. *Operculina hardiei*, d'Arch. & Haime (1*e*).
1916. non *Operculina hardiei*, d'Arch. & Haime, Douvillé (7*c*).

This species has been well described and figured by d'Archiac and Haime, the structure of the septa and chambers of the median chamber layer being shown in their pl. xxv, fig. 6*c*. In the specimens I have examined the diameter of the test has not been observed to exceed 3·5 mm., the average diameter being from 2 to 3 mm., and the average thickness 1 mm. The central part of the test, which bears granules, is generally elevated, the ornamentation being somewhat variable.

Douvillé has described an Operculine from Tibet under this name of which the diameter is more than 10 mm. In view of the large size of this specimen and the existence of a somewhat different ornamentation it is very doubtful if this is the same species.

Occurrence.—This species is locally very abundant, almost entirely making up thin limestone bands. (*a*) Below Trig. Station 685, near Leilan and other points in the Bund Vera Plain and the country south of Leilan, common. (*b*) One specimen S.W. of Hilaia Trig. Station, S.W. of Jherruck. Both coll. by C. and N.

Operculina sp. (Pl. XI, Figs. 5–6.)

I have examined only four specimens of this uncommon species. Owing to there being only a small number of specimens available the limits of variation of this species are not known, and in consequence it is at present undesirable to give this form a new specific name.

The average diameter of the above specimens is 8 mm. and thickness 1 mm. In a radius of 4 mm. there are four whorls, which increase gradually in width from the centre to the periphery. The equatorial section (Fig. 6) shows the form to be microspheric, the whorls very regular, the whorl laminae narrow, the septa evenly spaced, fairly thick, and curved near the exterior margin of successive whorl laminae. Externally each septum forms a ridge, which particularly in the young stage bears indistinct granules. The species is closely related to the European Lower Eocene form *O. granulosa* Leymerie (14*b*).

Occurrence.—Lower limestone terrace, Jherruck, I.G.S. No. G. 280/124*a*.

Genus Dictyoconoides Nuttall (= *Conulites* Carter, 1861).

Dictyoconoides conditi sp. nov. (Pl. XI, Figs. 7–8.)

Description.—Test conical with slightly convex base. Diameter of base from 1·5 to 2·8 mm., height of shell 1·0 to 1·9 mm. Exterior nearly smooth, except for indistinct granules at the apex. On the upper surface, whorl laminae are visible through the cortical layer. In axial section (Fig. 7) it is seen that the peripheral layer of rectangular chambers is wide with four whorls. Chambers about twice as high as long, the whorl laminae strongly curved outwards. In the median chamber layer are four vertical columns of shell matter, between which are narrow transverse septa curved downwards. In an horizontal section (Fig. 8), cut near the base, the chambers are about twice as long as broad, and are bounded by posteriorly-curved septa. The spire is simple, and there are no intercalated whorls.

Remarks.—The internal structure of this species is similar to that of *D. cooki* (Carter), the only other known species of the genus.[1] It differs from this by being much smaller and possessing fewer, somewhat differently arranged whorls and a much smaller number of vertical columns of shell substance (see Nuttall 15). The species is rare, the total number of specimens examined being only ten. It is named in honour of Mr. D. Dale Condit with whom I collaborated in geological work in India.

Occurrence.—(*a*) The lower terrace, Jherruck, I.G.S. No. G. 280/124*a*. (*b*) N.E. of Petiani, S.W. of Kotri, I.G.S. No. G. 280/135. (*c*) 5½ miles S.E. of Meting, coll. C. and N.

Genus Alveolina d'Orbigny.

Alveolina oblonga d'Orb.

I have recently figured and described this species from the Laki Series (16*b*), and the specimens found in the Upper Ranikot are small forms with a length of 2 to 3 mm. They occur as follows: (*a*) Lower terrace, Jherruck, I.G.S. No. G. 280/124*a* and C. and N. (*b*) N.E. of Petiani, N.W. of Kotri, I.G.S. No. G. 280/135. (*c*) 5½ miles S.E. of Meting, C. and N.

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[1] Since the above was written, Professor H. Douvillé has published a preliminary account of his study of the genus (C.R. Som. Soc. Géol. France, Feb. 1926, pp. 19–21).

Subgenus Flosculina Stache.

Flosculina globosa (Leymerie).

This species I have also described from the Laki Series (16*c*). The forms that occur in the Upper Ranikot are about 2 to 2·5 mm. in length and possess an average of three widely spaced whorls. I have examined specimens from the following localities: (*a*) S.W. of Hilaia Trig. Sta., S.W. of Jherruck. (*b*) 5½ miles S.E. of Meting. Both coll. C. and N.

Genus Discocyclina Gümbel.

Discocyclina sp. ind.

One species of *Discocyclina* is fairly common, and is found in a poor state of preservation. The average diameter of the test is 7 mm. and thickness about 1 mm. The surface is covered with fine granulations of equal size and in close proximity. It occurs as follows: (*a*) Lower terrace, Jherruck, I.G.S. No. G. 280/124*a* and C. and N. (*b*) N.E. of Petiani, I.G.S. No. G. 280/135. (*c*) Near Trig. Station, 685, Leilan., coll. C. and N.

EXPLANATION OF PLATES.

Plate X.

Figs.

1–2.—*Nummulites planulatus* (Lam.). Lower terrace limestone, Jherruck. I.G.S. No. G. 280/124*a*. × 4.

3–4.—*Nummulites guettardi* D'Arch. 5½ miles S.E. of Meting. Coll. C. and N. × 8.

5–6.—*Siderolites miscella* (D'Arch. and Haime). S.W. of Hilaia Trig. Station, S.W. of Jherruck. Coll. C. and N. × 8.

7–11.—*Assilina ranikoti* sp. nov. × 8. Fig. 7, 5½ miles S.E. of Meting, coll. C. and N. Figs. 8 and 11, Lower terrace, Jherruck, I.G.S. No. G. 280/124*a*. Fig. 11, equatorial section showing polished surface. Figs. 9 and 10, S.W. of Hilaia Trig. Station. Fig. 9, Holotype. Coll. C. and N.

Plate XI.

1–2.—*Operculina canalifera* D'Arch. Lower terrace, Jherruck. I.G.S. No. G. 280/124*a*. × 4.

3–4.—*Operculina hardiei* D'Arch. and Haime. Below Trig. Station 685, near Leilan. Coll. C. and N. × 8.

5–6.—*Operculina* sp. Lower terrace, Jherruck. I.G.S. No. G. 280/124*a*. × 4. Fig. 6, equatorial section showing polished surface.

7–8.—*Dictyoconoides conditi* sp. nov. × 16. Fig. 7, holotype. Thin sections, 5½ miles S.E. of Meting. Coll. C. and N.

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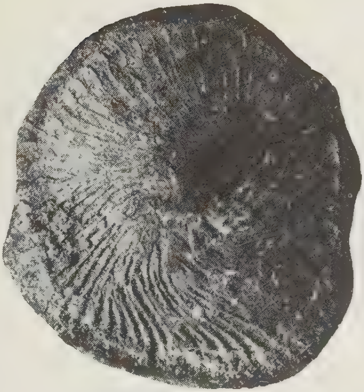
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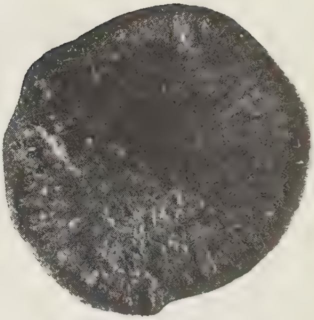
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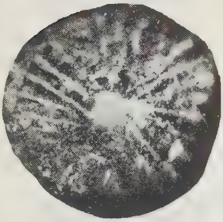
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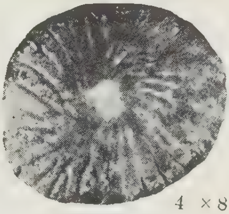
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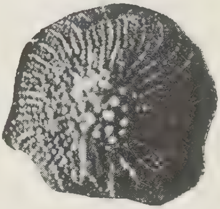
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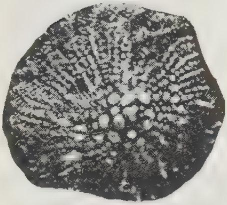
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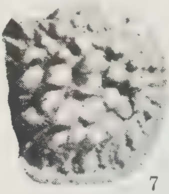
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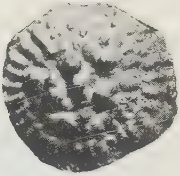
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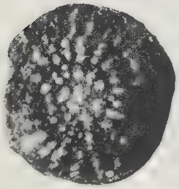
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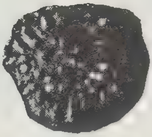
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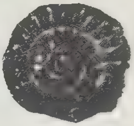
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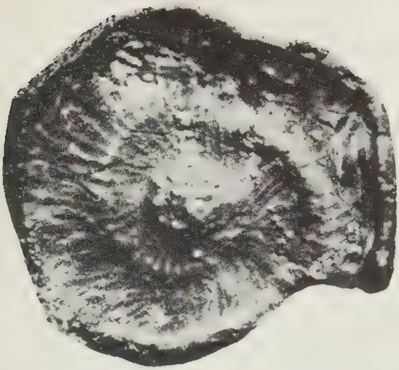
Microphoto by W. L. F. N.

NUMMULITES, SIDEROLITES, AND ASSILINA.

[*To face p. 120.*



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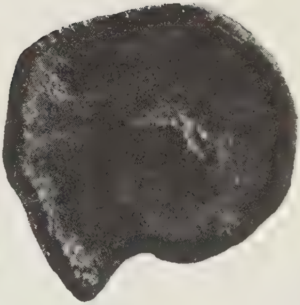

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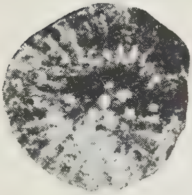

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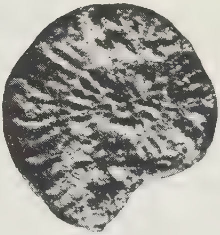

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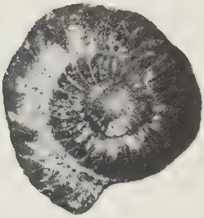

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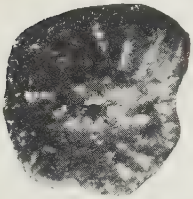

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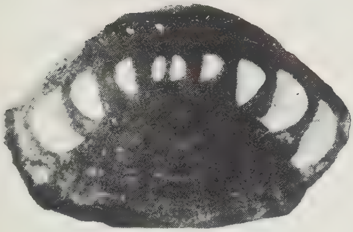

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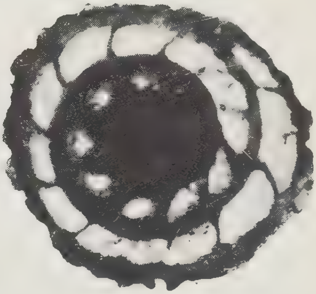

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The Bala-Silurian Succession in the Llangranog District (South Cardiganshire).

By E. M. LIND HENDRIKS.

(PLATES XII–XIV.)

I. INTRODUCTION.
II. THE SUCCESSION.
III. DETAILED DESCRIPTION OF THE BEDS.
IV. GENERAL STRUCTURE.
V. COMPARISON WITH OTHER AREAS.
NOTE ON THE GNARLED MUDSTONE.

I. INTRODUCTION.

THE area examined occupies about 12 square miles in South Cardiganshire bounded inland by a line joining the hamlets of Sarnau and Nanternis, and extending along the coast from the stream crossing Penbryn Sands in the south to New Quay in the north.

This area has been hitherto almost entirely neglected, the only reference found to it being in a paper by Professor O. T. Jones, in which the Upper Hartfell or Upper Bala age of the rocks (*Truncatus* beds) south of Penbryn is indicated. Dr. Jones adds " There is little doubt that we reach here the junction between the Bala and the Silurian rocks sought for by Keeping . . . This section requires further investigation, but it is only at certain times that the state of the tide will admit of its examination ", and it was this sentence which tempted the writer to tackle the problem. The present description " summarizes " the results of six months' field-work in 1923 and 1924 and of a few subsequent visits. I am greatly indebted to Mr. D. C. Evans, who during the last fifteen years has mapped the country to the south, both for his encouragement and for his permission to offer these notes for publication.

I wish also to express my thanks to Professor O. T. Jones and to Dr. Gertrude Elles for their kindness in naming some of the graptolites.

II. THE SUCCESSION.

The rocks comprise mudstones and shales, flags, gritty and flaggy mudstones, and grits with subordinate conglomerates. They fall naturally into three main groups, which have again been subdivided in descending order as follows :—

UPPER VALENTIAN		The Aberystwyth Grits.
	Upper Birkhill	Pale mudstones, representing the zones of *M. convolutus* to *M. turriculatus*.
LOWER VALENTIAN	Middle Birkhill	Thin grits, *M. gregarius* at base, *M. triangulatus* fauna near middle, *M. decipiens* at top.
	Lower Birkhill	Orange-weathering shales, with fossils ranging from *G. persculptus* to *M. cyphus*.
	" Gnarled grits "	Pyritous mudstone. Ribbony beds (grit stripes in mudstones). Massive grits ⇄ thin grits ⇄. gritty mudstones.
	" Gnarled mudstone "	Knotted blue mudstone with contorted grit structures.
UPPER HARTFELL or UPPER BALA	*Truncatus* beds	Thin grits (" *Truncatus* grits "). Ribbony beds (grit stripes in mudstone). Pale, mottled mudstones and lemon-weathering shales with *O. truncatus* var. *abbreviatus*, etc.

The estimated thicknesses are indicated in diagrammatic vertical sections, Figs. 5 and 6, pp. 137–8.

III. DETAILED DESCRIPTION OF THE BEDS.

It is convenient in general to follow the coast from Penbryn in a N.E. direction, describing the beds in the order in which they are thus met with, i.e. in ascending order, from the oldest (*Truncatus* beds) at Penbryn to the youngest (Aberystwyth Grits), which first appear in Moel Ciliau and extend through New Quay. One unit, however, the gnarled mudstone, achieves its best development only at Pen-y-Billies, Lochtyn, S.W. of which it is recognizable only in isolated patches: it will thus be necessary to trace this mudstone in a direction contrary to that followed in the general account.

The Truncatus Beds.

At and south of Penbryn Sands the cliffs are composed of thick-bedded, olive-green or grey-blue, mottled mudstones, often with a faint parallel striping in addition to the mottling. The latter occurs in streaks or blotches, often measuring about an inch in length and one-eighth of an inch in breadth, sometimes with a forked or irregular shape.

In the first cove north of Penbryn Sands, near the top of the mudstones, is a brilliantly lemon- or orange-weathering shale belt, some 80 feet in thickness, near the base of which were obtained numbers of *Orthograptus truncatus* var. *abbreviatus*, beautifully preserved in full relief in pyrite, together with some poor specimens of *Climacograptus scalaris* var. *miserabilis* (see map, Fig. 1). Just below the top of the mudstone, groups of thin, crinkled ribbony stripes of grit make their appearance and become gradually thicker and more frequent until they pass into a thin belt (60 feet or so) of thin-bedded grits. These grits are tough, compact, pale blue-grey, usually highly micaceous, often non-laminated, sometimes with an appearance that is almost schistose. They are quite distinctive and clearly recognizable from any of the different types of "gnarled" grits presently to be described. In the third cove north of Penbryn Sands their upper part, as shown in Plate XIII, is highly disturbed. The *Truncatus* mudstones and shales are exposed on the south side of Penbryn Valley below the Church.

The Gnarled Mudstone.

In the cliffs and islet (Careg y Nedwydd), south of Traeth Bach, the *Truncatus* grits are succeeded by a very distinctive mudstone and grit rock, entirely unlike any of the other rocks of the locality.

The rock is an unbedded, dark-blue, gritty, gnarled-looking mudstone. It often breaks up into curved, sharp-edged tentacles with polished surfaces and shows a knotted structure both externally and when broken. In the mudstone are embedded curiously twisted, often massive, grit-structures (see Plates XII and XIII), whose presence gives the rock its distinctive character. The grit-structures occur either in groups, or in isolated twisted, or boulder-like masses;

but however they occur, they are apparently invariably contorted, and when fractured display curved, twisted and knotted laminae. Although the containing mudstone is unbedded, in several localities (e.g. Lochtyn) the dips of the overlying rocks suggest that it is strongly folded, but both here and at Penbryn the disposition of the grit-structures is quite unrelated to the bedding of the associated rocks. As an indication of scale, it may be mentioned that one

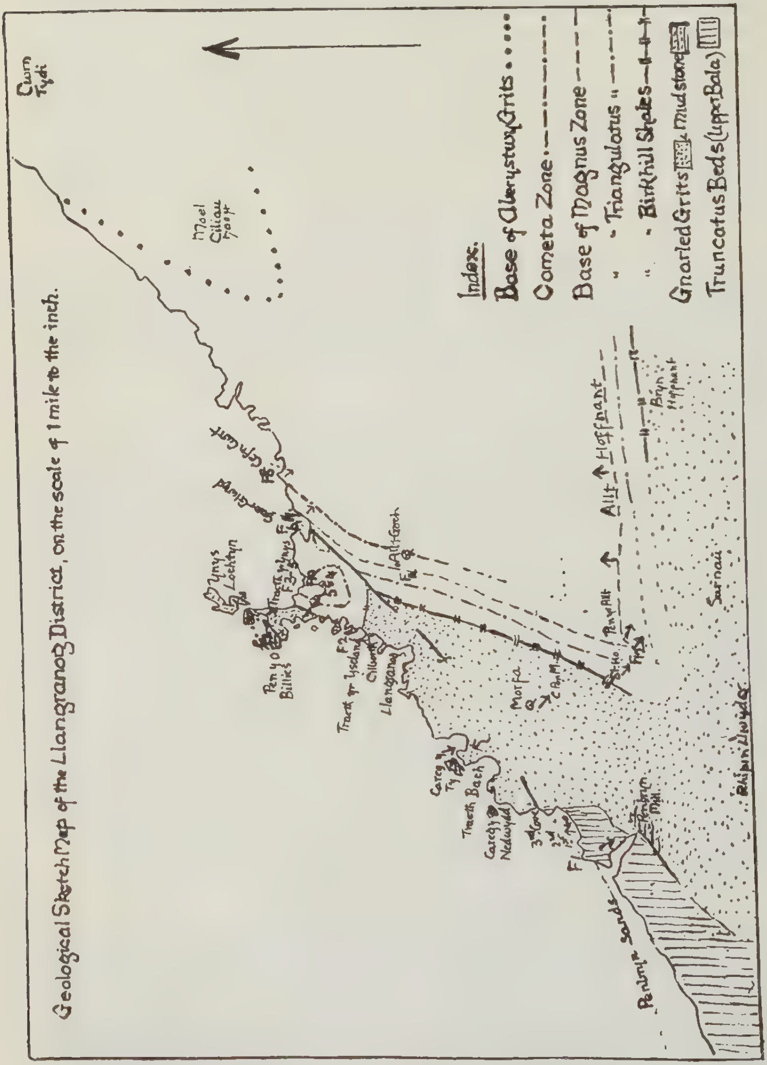
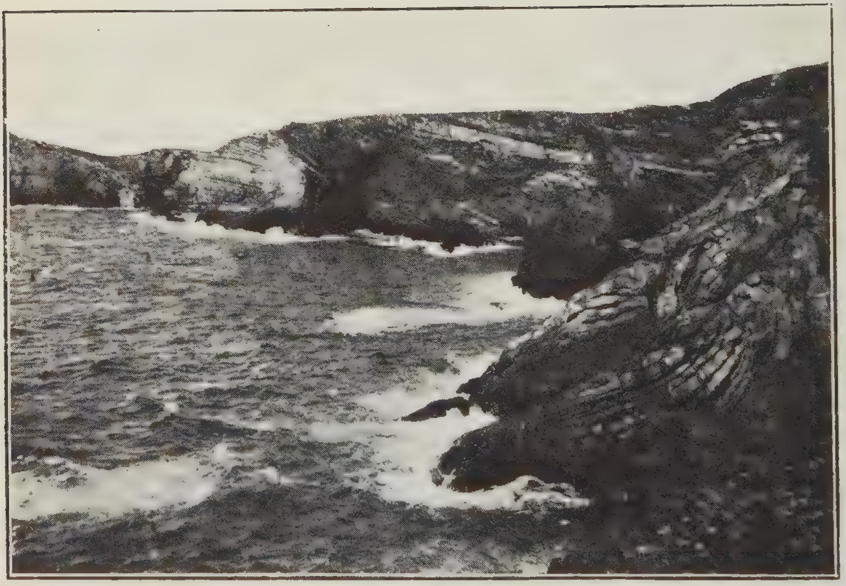


FIG. 1. Sketch-map of the Llangranog district.



Photograph 1.—From Pen-y-Billies, looking East.

In foreground and at base of opposite cliff, gnarled mudstone with grit structures. Note thickness, and compare with Photograph 2. Facing camera, gnarled grits. The thin grits are false-bedded below and are thrust against massive grits (on left). On extreme left, the massive grits of Ynys Lochtyn.

of the grit masses north of Penbryn is known to boatmen as the "Grey Dog" ("Ci Llwyd") and is used as a landmark.

The distinctive character of this rock rendered it useful as a fixed horizon in early attempts to group the whole local series (see note).

The gnarled mudstone builds cliffs 100 feet high at the end of the Lochtyn peninsula (Pen-y-Billies), where it underlies the massive grits of the Island (Ynys Lochtyn) and thin grits are thrust against it (Plate XII). This thrust passes across the end of the peninsula in a south-westerly direction, as shown on the map. Owing to the shape of the coast, the mudstone is next seen only at Traeth Bach, where it underlies the thin grits of the Gnarled Series in the Careg y Ty syncline and to the south. In Careg y Nedwydd the base is seen, resting on *Truncatus* grits. South of this point, the base again falls below sea-level, but rises to nearly the middle of the cliff in the third cove north of Penbryn Sands. In the latter locality, the rock has become reduced in thickness to a mere wedge-shaped sandwich between the two series of grits. The nose, or thin edge of the wedge, is displaced by the fault which brings together massive and thin-bedded grits in the upper part of the cliff (Plate XII, 2). As the photograph shows, the mudstone then dies out completely, leaving gnarled grits resting directly upon *Truncatus* grits, the upper part of the latter being highly disturbed. Even if this disturbance be due to a thrust, the fact that the mudstone dies out at this point cannot be overlooked.

The mudstone reappears beneath the gritty-mudstone facies of the gnarled grits at the mill in the floor of the Penbryn Valley (Hoffnant), whence it has been traced northwards in the secondary anticline which passes through the high ground to the south-west of Llangranog.

The Gnarled Grits.

These occupy the whole of the coastal section from Penbryn to Ynys Lochtyn, and are characterized by the frequency and suddenness of their lateral variations.

The rocks on this horizon are (*a*) thin grits; (*b*) grey-blue gritty mudstone; (*c*) massive grits.

The first two pass into one another—as on the south side of Traeth Bach—abruptly; but where (*a*) and (*c*) are in juxtaposition, the junction is usually faulted. A coarse conglomerate containing subangular fragments of mudstone, both grey and dark blue, together with pebbles of grit, is ploughed up in large blocks from the base of (*c*) around Morfa quarry.

(*a*) *The thin grits* are usually grey and glossy with curved or twisted laminae. If at all micaceous, they are markedly less so than either the *Truncatus* or the Birkhill grits. At Lochtyn they are false-bedded in their lower part (Plate XII). They are characterized by ripple and other markings, including worm-trails and molluscan tracks, indicative of shallow-water conditions. These may be seen all along the coast from Traeth Bach to Lochtyn. At the former locality occur thin bands resembling the underlying group, but distinct from the latter in the same way that shale bands in mudstone are distinct from a shale group.

(*b*) *The gritty mudstone* lacks both the twisted structure and " polished " cleavage of the underlying group. It is easily recognized by its blue-grey colour, rusty weathering, and gritty texture, together with the absence of grits, and the peculiar, large, irregularly shaped sharp-edged blocks into which it breaks up. The rock is well developed around and south of Morfa Penbryn, and in the cliffs south of Traeth Bach.

(*c*) *The massive grits* and quartzite have been traced in patches with an easterly strike through Sarnau and Phipin Llwyd quarry where they turn north, cap the hill known as Morfa Banc, occur in small isolated patches at gradually decreasing altitudes between that point and Llangranog, and are last seen in the island, Ynys Lochtyn. In the latter locality, (*a*) and (*c*) rest upon gnarled mudstone ; at Penbryn, partly upon gnarled mudstone and partly on *Truncatus* beds.

The massive grits are similar lithologically to the thin grits, but the beds may average about 3 feet in thickness. A bright blue, very tough variety favoured for road-metal is frequently interbedded with a buff-coloured type. Where the beds are vertical, striking ripple-markings are visible on their bases. Between the beds occur thin conglomerates, pale well-cleaved slates or flags with worm-trails, pale striped greenish-grey, soft-weathering shales, and dark-blue rusty-weathering flags. No fossils have been found.

(*a*), (*b*), and (*c*) are overlain by beds of more constant character. In the lower part of these beds, which are about 80 feet thick all told, the grits begin to degenerate into belts of mere strips, always " crinkled ", i.e. thrown into a beautiful series of miniature folds. The mudstone bands gradually predominate until beds of 15 feet or so are achieved. Such a series appears in Llangranog Cove and the Cilborth, and provided a clue to the horizon along the east side of the anticline. The mudstones of these bands are homogeneous, and break up into long, more or less rectangular pencil or finger-like fragments. Some of them, as on the south side of Traeth Bach, are very well-cleaved and on account of the rusty tints in which they stain on weathering strongly resemble parts of the Lower Birkhill shales. The highest bed of the series is a belt of about 50 feet of massive dark-blue rusty weathering pyritous mudstone. The upper part of it is in places very well cleaved, and then consists of blue flags which are apparently barren and stain on weathering in bright-coloured concentric rings. This readily identifiable mudstone-belt forms a slight feature, easily mapped, at the base of the Birkhill shales, whereas the shales themselves usually occupy a grass-covered hollow, rendered marshy

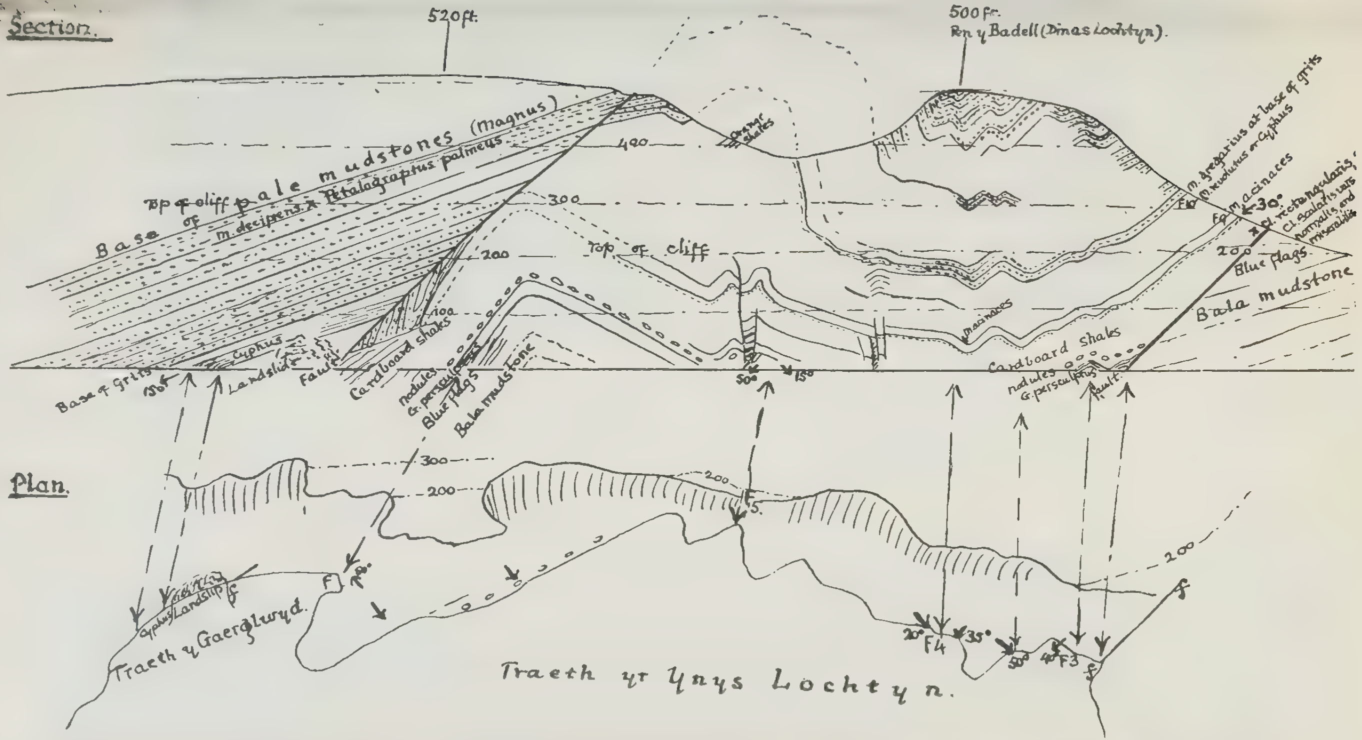


FIG. 2.—Plan and sketch-section of Traeth yr Ynys Lochtyn and Traeth y Gaerglwyd, to show general structure (line 2 on map). Horizontal scale, 1 inch = 400 ft. Vertical scale of section, 300 ft. to the inch (approximately). Length of section, half a mile.

along the junction by a line of springs. This marshy hollow constitutes an equally useful horizon for mapping purposes (see Pl. XIII, 3). In other districts the summit of the mudstone is taken as the dividing line between the Ordovician and Silurian systems owing to the lithological change at the base of the overlying orange-weathering Lower Birkhill Shales. The junction in the Llangranog country is perfectly conformable if at times slightly faulted.

No fossils have so far been found in the Gnarled Series.

The Lower Valentian rocks may be best dealt with in the course of an attempt to describe in detail the sections where they are best exposed. These fall under four heads, i.e.

(1) (*a*) The Traeth yr Yscland; (*b*) Traeth yr Ynys Lochtyn-Gaerglwyd; and (*c*) Cefn Cwrt, coast sections.

(2) The Moel Ciliau-Cwm Tydi section.

(3) The road sections in and around Llangranog village.

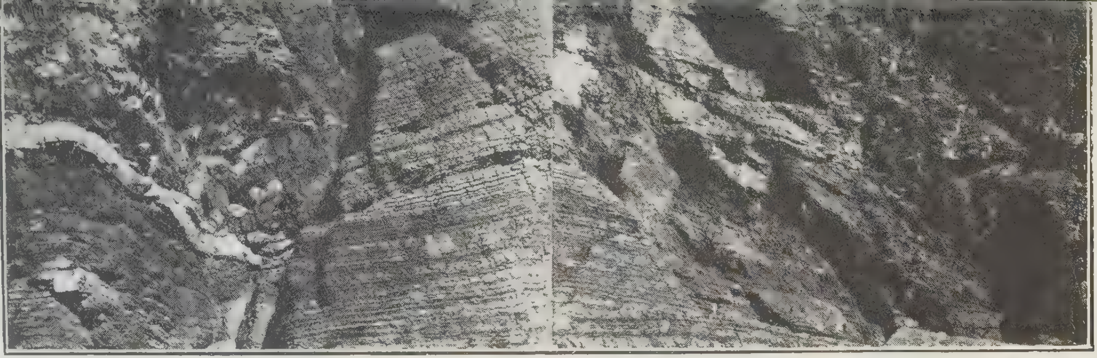
(4) Several scattered exposures along the Hoffnant escarpment.

(*a*) *The Traeth yr Yscland Section.*—This important section, probably the only locality yet found in which the base of the Birkhill Shales is displayed, is only intermittently available, and then only at Spring-tides, owing to the effects of frequent changes in the level of the sand. During the whole summer of 1923, a narrow path cut into the vertical or overhanging cliff-face was the only means of approach. At the top of the pyritous mudstone belt in this locality is a grit-band above which in a syncline lie the "orange-weathering shales" (Fig. 2). A similar grit-band has been observed at a corresponding horizon in other districts (5). The debris of a scree-filled gully at the junction supplied a variety of Lower Valentian climaco-graptids, with one recognizable *Cl. rectangularis,* in varying stages of decay. The shales in situ are here out of reach. The photograph and fig. show, in the foreground, a slight fault at the junction which, in the further cliff, is perfectly normal. It also shows the abruptness of the lithological change from the tough, massive pyritous blue mudstone to the soft, black, orange-weathering shales.

At the north-east end of Traeth yr Yscland the coast becomes inaccessible, and the shales themselves are still out of reach. Where next met with, in Traeth yr Ynys Lochtyn, the pitch has carried their base below the level of the beach, and it is only in the anticline at the west corner of Traeth y Gaer-glwyd that the thickness of the *persculptus* shales can be estimated.

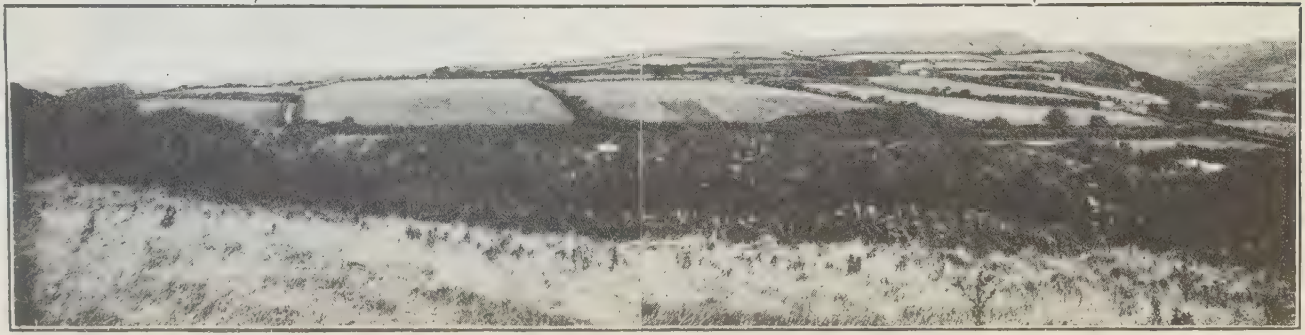
(1) (*b*) *The Traeth yr Ynys-Gaer Glwyd Section* (*Fig.* 2).

This section comprises horizons ranging from the zone of *Glyptograptus persculptus* to the base of the zone of *M. convolutus*, as determined by the collection of representative assemblages at various points.

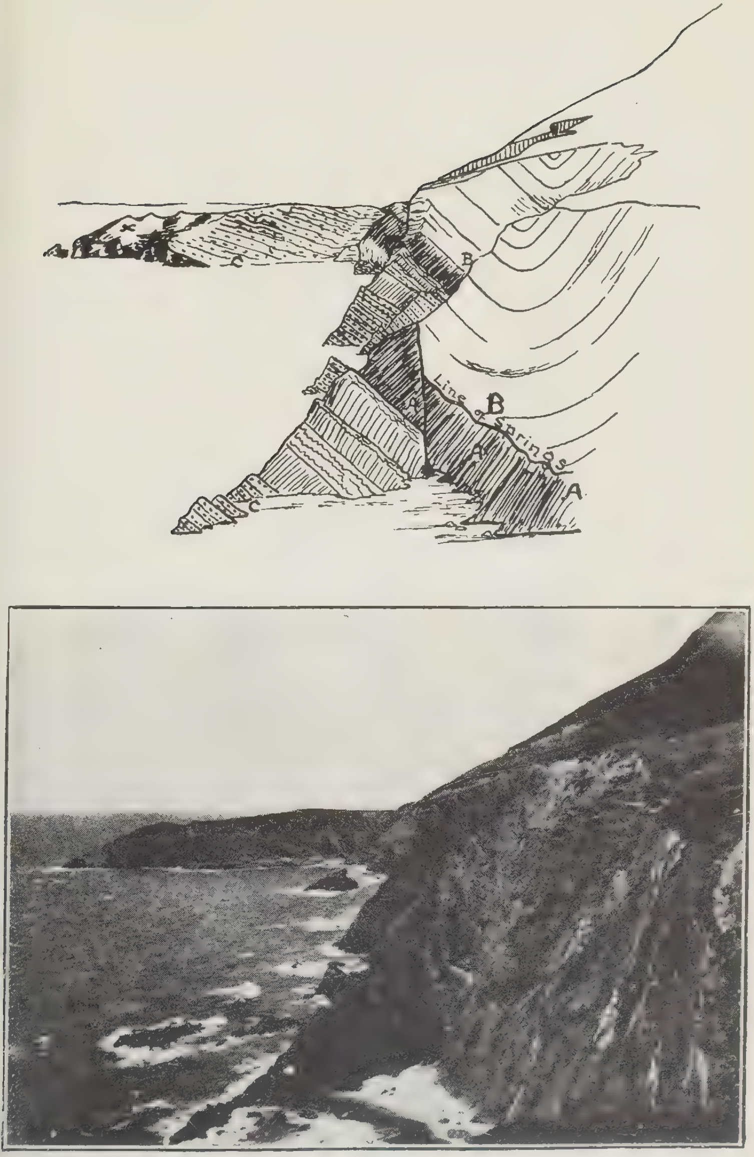


PHOTOGRAPH 2.—THIRD COVE NORTH OF PENBRYN SANDS.

Thinning out of gnarled mudstone. The mudstone with grit structures, shown on left, is reduced to a thin band resting on *Truncatus* grits. Compare with Photograph 1, and note grit-band at base. The mudstone passes behind the stack, where it is first faulted, then thins out completely (beneath arrow), leaving gnarled grits resting on highly disturbed *Truncatus* grits.



3.—VIEW ACROSS THE SYNCLINE FROM MORFA BANC, LOOKING EAST.



THE BALA-SILURIAN JUNCTION IN TRAETH YR YSCLAND.

B. Lower Birkhill Shales. A. Pyritous Mudstone.
C. Gnarled Grits. X. Gnarled Mudstone.

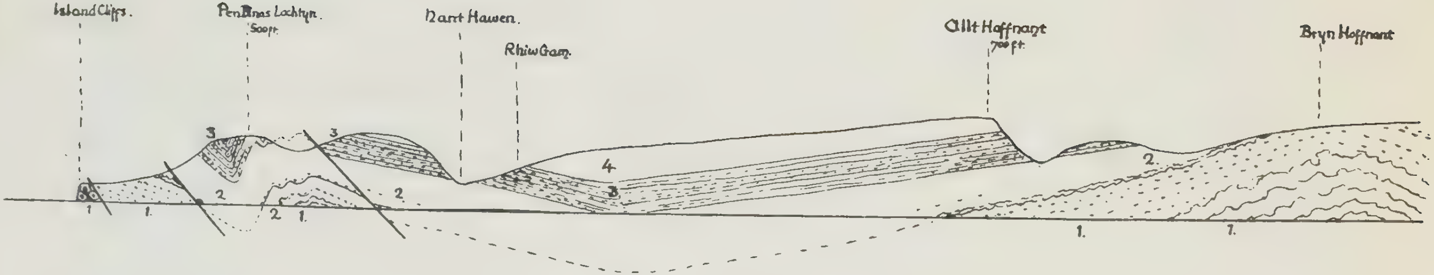


FIG. 3.—Generalized section across the Synclinorium, on the scale of 3 inches to the mile. Vertical scale, 1000 feet to the inch (line 1 on map).
4. *Magnus* Mudstones. 3. Thin grits with *M. triangulatus*, etc., near middle. 2. Zones *G. persculptus* to *M. cyphus*.
≈≈≈ Pyritous mudstone (flags in places at top). 1. Gnarled grits, etc.

In the corner of the "bathing cove" (Traeth yr Ynys) at the foot of Lochtyn Hill, the faulted junction of Lower Birkhill "orange-weathering shales" and pyritous mudstone is again seen. Although the fault carries breccia, the throw is probably not more than about 30 feet, as judged from the disappearance of the *persculptus* flags, and a comparison with the Yscland and Gaer Glwyd exposures.

The beds in this section lend themselves to subdivision into zones both on faunistic and lithological grounds.

The lowest zone consists of black pyritous shales with rusty staining. About 20 feet of these shales are brought up in a small anticline near the foot of the path, but as already mentioned, their base is not here seen. A conspicuous feature is the presence of several relatively pale bands, averaging 1½ inches in thickness. These bands are conspicuous owing to the presence of swarms of small dark-coloured inclusions, which give rise to a very fine mottling or flecking. The mottling is, however, quite different from that in the *Truncatus* beds at Penbryn, being very much smaller and closer.

About 18 inches below the lowest visible mottled band, near the average level of the sand, but about 2 feet above the rocky floor, is a shale-band swarming with somewhat narrow specimens of *G. persculptus* well preserved in relief in pyrite. At a slightly higher level numbers of *Climacograptus scalaris* vars. *normalis* and *miserabilis*, together with *Climacogr. rectangularis* and *Orthoceras*, were collected. *Orthoceras* also occurs in the rock-floor of the cove at this point (Fig. 2). These beds are characterized by the presence of very small nodules of pyrite, which occur in large numbers. Roughly 10 feet above the *persculptus* band is a very thin and soft shale band crowded with specimens of *Climacograptus scalaris* var. *normalis*, magnificently preserved in full relief in pyrite. Twenty to 25 feet above the *persculptus* band, large calcareous nodules appear, amongst which the same fossils were obtained, with the exceptions of *G. persculptus* and *Orthoceras*. The nodule belt is approximately 30 feet thick, and as *G. persculptus* has not so far been found above its base, it is provisionally included with the *acuminatus* zone. The beds associated with the highest nodules are hard blue compact flags or flaggy mudstone recognized in a similar position also at the east end of the Traeth, and in both localities yielding similar characteristically compressed specimens of *Cl. scalaris* var. *normalis*.

The nodules are succeeded by a well-marked belt of tough shales in which fossils are scarce. These beds often, noticeably in the west limbs of the folds, break up in flat cardboard-like sheets, but in the east limbs this structure is often obscured by a second cleavage or other cause, giving to the beds quite a massive appearance and in this case they break up into more or less finger-like pieces. The beds may, however, be easily identified even where the peculiar "cardboard cleavage" is lost, by means of the characteristic rusty-greenish tints in which they stain on weathering. Their distribution is indicated in the section, Fig. 2.

In the corner marked F 5 *Mesograptus modestus* var. *parvulus*, crowds of *Cl. scalaris normalis*, and one poor example of *C. ? acuminatus* and *Cl. hughesi* were obtained. It is therefore suggested that this belt represents the *C. acuminatus* zone.

The thickness of the shales in the first two synclines is estimated at about 50 feet.

The top of the belt is taken at the lithological change about 4 feet below a rather prominent group of very thin grit bands, which can be followed for some distance.

About 4 feet below these grits, in the second syncline, hard blue flags just above the cardboard shales yielded the following species, marking a new zone :—

Climacograptus medius.
,, *törnquisti.*
,, *scalaris normalis* and, in debris of doubtful derivation, *Monograptus atavus.*

Approximately 10 feet above the grits, *M. acinaces* occurred.

A digression is here necessary in order to describe the higher beds as exposed in the path section half-way up Lochtyn Hill.

The group of grit stripes passes through the first syncline of the foreshore and then swings up the cliff at nearly 40° towards Lochtyn path, at the western bend of which they are again found, dipping at E 30. At this point (F 9 on map) were obtained—

Monograptus acinaces.
Climacograptus medius.
,, *törnquisti.*
,, *rectangularis.*
,, *scalaris.*

Lochtyn path is here almost level, at 270 feet or so O.D. It just crosses the 300 feet contour on the north side of the hill.

At the north corner of the path (F 10 on map)—

**Monograptus revolutus* or *cyphus* was obtained from badly weathered material having the same dip. Five yards further east begin the grits of which Lochtyn hill is composed. At their base are black shales with peculiar gritty surfaces which weather ashy white. The shales also stain a pale buff colour, and contain very thin, pale, sandy stripes. Nothing like them has been found at any other horizon.

They yielded—

**Monograptus gregarius* (siculae).
Climacograptus hughesi and *Cl. törnquisti.*

As seen from the beach, the beds which succeed the " cardboard " shales are very rusty in places, but are too high in the cliff to be searched for fossils. At the top of Lochtyn Hill, in the grits, a poor specimen of *M. atavus* was found.

We now return to the foreshore.

As shown in Fig. 2 the Lochtyn beds are strongly folded, but the faulting is not considerable.

At the east end of Traeth yr Ynys, the nodules reappear. At the very end of the beach, where it becomes inaccessible, the axis of the fold is parallel with the base of the cliff, up which the beds swing steeply. Thus a large surface of the nodule beds is exposed, giving the misleading effect of a much greater number of nodules than occur at the west end of the Traeth. This anticline is important because in it the base of the *persculptus* zone occurs. It may be best examined from Traeth Gaerglwyd, where the pyritous mudstone passes up gradually into well-cleaved blue flags, dipping E. at 50°. Above the flags are about 20 feet of black shales, the junction as usual occupying a scree-filled gully, but no fault is apparent. The shales are followed by beds with large calcareous nodules. Immediately beneath the nodules the shales yielded—

Glyptograptus persculptus.
Climacograptus rectangularis.
,, *scalaris* var. *miserabilis* and *Orthoceras.*

thus proving the nodules to be the same as those at the west end of Traeth yr Ynys. As in the latter locality, the beds contain numbers of small nodules of pyrite.

It is clear that at this point there is no sharp demarcation between the *persculptus* beds and the pyritous mudstone. It would seem natural to include the shales and flags in one group. For this reason no estimation of the thickness of the *persculptus* beds as a whole can be given.

In Traeth y Gaerglwyd, the nodules are, as before, succeeded by "cardboard shales," in which no fossils were found. Beds containing thin grits are thrust over them (Fig. 2). Near the middle of the cove a considerable fault occurs. Just east of the fault the cliff section is obscured by a land-slide which occurred in 1885, and has left an obvious scar on the cliff face near the top, i.e. at about 300 feet O.D. Debris in this fallen mass yielded, on one slab—

Monograptus communis.
Petalograptus minor.
Climacograptus scalaris.
,, *törnquisti* (in numbers).

The fossils are preserved in full relief on the surfaces of thin-bedded, dark blue-grey, micaceous grits, coated with a silvery mud-film which has preserved in detail, as well as the graptolites, the ripple-markings, worm trails, and molluscan tracks. It is interesting that Graptolites should occur in such an association.

Twenty yards east of the land slide, in a 20 foot belt the upper limit of which is 10 feet beneath the base of the grits, smooth blue flags at the base of the cliff yielded the following *Cyphus* zone assemblage :—

M. revolutus. M. atavus.
M. sandersoni.
M. acinaces.
M. cyphus.
M. incommodus.
Cl. törnquisti.

confirming the evidence of the Lochtyn path.

The dip is S.E. 15°. The cliff is here vertical, over 300 feet high, and composed of thin-bedded grits.

At the summit of the cliff, the grits pass up into pale mudstones, striped with sandy seams. These mudstones are in places sufficiently well cleaved to have been tried for slates. No identifiable fossils have yet been found in them along the coast between Gaerglwyd and Cefn Cwrt, but from those obtained from the landslide which came from near their base (Fig. 2) and from others to be mentioned later, it is concluded that their base may be taken, within a few feet, as the beginning of a new zone, i.e. that of *Mesograptus magnus.*

As far as Cefn Cwrt a general south-south-easterly dip is maintained.

(c) *The Cefn Cwrt Section.*—In Traeth Cefn Cwrt a rich shale-band yielded a *Cometa* zone assemblage in abundance as follows:—

Monograptus sedgwicki.
,, *lobiferus.*
,, *leptotheca.*
,, cf. *elongatus.*

Monograptus crenularis.
,, *tenuis.*
Cephalograptus cometa.
Climacograptus hughesi.
,, *? scalaris.*
Rastrites peregrinus.

2. *The Moel Ciliau-Cwm Tydi Section.*

At Moel Ciliau the pale mudstones are overlain by the conglomeratic base of the thick-bedded or massive grit which represent the basal beds of the Aberystwyth grit group.

Although less folded than the underlying mudstones between Moel Ciliau and Cwm Tydi, the relations at the point where the grits come down to the beach, on the south-west side of Cwm Tydi, appear conformable. The grits are thrown into a fine series of asymmetrical folds which occupy the coast-line between Cwm Tydi and New Quay. At Nanternis the normal development of Aberystwyth grits is seen. The beds beneath the grits at Cwm Tydi are hard, pale shales, but no fossils were found.

3. *The Road Sections around Llangranog Village.*

The orange-weathering Lower Birkhill shales have been traced by means of fragments thrown out in rabbit scratchings through the hollow followed by the telegraph poles in the hill north of the village, where they are faulted against the underlying beds. This is evidently the continuation of the Gaerglwyd fault. It passes through the notch in the ridge to the south, where massive and thin grits are brought together with an opposing dip, and thence, through a slight hollow on the opposite side of the valley, out to the coast north of Penbryn, as already seen. The shales cross the valley and pass west of the wood (Troed Rhiwgam). The wool factory and spring mark the junction.

The thin-bedded grits of Lochtyn Hill and Caer Glwyd form well-marked cliffs at the back of Llangranog Church and Post Office. Although much folded, they still have a general south-easterly dip.

The grits in Llangranog village, 50 to 60 yards up the road east of the Post Office, yielded the following assemblage, which may be assigned to the base of the *M. triangulatus* zone :—

**M. atavus.*
**M. communis.*
M. triangulatus.
**M.* ,, var. *raitzhainiensis.*
**M. revolutus* var. *praecursor.*
Cl. törnquisti (abundant).
Cl. rectangularis.
G. (?) *sinuatus* and *dendroid graptolites.*

At Allt Goch quarry, the grits pass up into the pale mudstones.

At the Post Office, the strike swings across the valley nearly S.W. carrying the base of the grits through the south-west corner of the wood (Troedrhiwgam), while their summit is exposed in the road-cutting below the Sunday School. At Rhiwgam a badly preserved form suggestive of *Mesograptus magnus* was obtained.

A search was made for fossils in the pale mudstones near the school and also in Nant Ty, but without success. From Rhiwgam to the Hoffnant, the outcrops have been traced by means of the features already indicated.

4. *The Hoffnant Exposures.*

The marshy hollow and mudstone feature have been recognized near Llech yr Ochain, and confirmed by the occurrence of orange-weathering shales in the road at Fron-lwyd (N.E. of Capel Pen Morfa) and again at the corner of the wood near Stanley House. At the latter locality the lithology closely resembles that of the shales at the base of the grits on Lochtyn Hill, but the material is badly weathered and only *Cl. törnquisti* and a few unidentifiable fragments were obtained.

From a quarry in the wood below Pen yr Allt Perth Neidr (F 12) 200 yards east of the Stanley House exposure, and just below the base of the pale mudstones, the following assemblage was obtained :—

M. triangulatus var. *raitzhainiensis.*
M. fimbriatus.
M. triangulatus.
M. (?) *communis* var. *rostratus.*
M. communis.
Cl. törnquisti.
Cl. scalaris var. *normalis.*

The dip is here south-east, in the quarry above, east, and immediately after becomes northward. The northward dip in the pale mudstones is maintained throughout the line of crags which form the north side of the Hoffnant; those crags therefore constitute a true escarpment. A relatively softer belt near the top of them, 220 yards south of Nant y Mawr farm, and again at Blaen Cwm, yielded *Mesograptus magnus*. This belt weathers in unmistakable greenish-buff colours, and breaks up into oblong rectangular pieces. Exactly similar beds have been observed at Capel Ffynon. As no other fossil has been found in them, the beds are referred to the *Magnus* mudstones.

IV. General Structure.

It has been shown that in taking Penbryn as the starting point, and proceeding thence either due east, or north-eastwards along the coast, successively newer beds are met with. It also happens that the base of each succeeding group is met with at successively lower levels. This is particularly evident when following the coast-line, for where first seen at Penbryn, the base of the massive grits (gnarled grits) for example, is at 300 feet O.D. in Morfa Banc, and where last seen at Ynys Lochtyn on the east side of the island, it is below sea-level. Similarly with the Birkhill shales, pale mudstones, and Aberystwyth grits. In this behaviour the gnarled mudstone alone is anomalous owing to the attenuation at Penbryn.

From these facts it follows that all the beds, which are strongly folded, plunge under one another in such a manner that the pitch must have an approximate average value of something like E. 30 N. at 16°. Actual measurements show variability of the angle of pitch between 15° and 19° at different points.

Further, the crests of the minor folds sometimes slope in the reverse direction, for example, a small (tertiary) anticline passing through the rocks Careg Bicca in Llangranog Cove (gnarled grits) pitches to the south-west at 18°.

This suggests pressure from a direction across that which produced the main folding. Such pressure may be in this locality not unconnected with the pencil-cleavage of so many of the homogeneous mudstone beds (although in South Wales the same characteristic has been ascribed to the nature of the sediments (2)[1]).

The most salient feature on entering the district from the south, is the line of crags forming the northern side of the Hoffnant. These with their northerly dip constitute a fine escarpment which, when considered in conjunction with the south-south-easterly dip around Cefn Cwrt, constitutes the southern limb of the Synclinorium which is the main structure of the district (Fig. 3). The synclinal structure is further indicated by the position of the Aberystwyth grits at Moel Ciliau. The Hoffnant crags are succeeded by successively older beds in a southerly direction. A secondary syncline is a conspicuous feature in the cliffs from Traeth Bach to Lochtyn, while its complementary anticline has been traced by means of the gnarled mudstone, etc., to the south-west of Llangranog through Morfa. Structures still smaller than the tertiary folds already alluded to, indicate the extent of the crumpling, which is reflected even in the folding of the thin ribbony stripes of grit within some of the mudstone beds.

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[1] Figures in parentheses refer to Bibliography at end of paper.

In following the secondary folding along the coast, a conspicuous feature is the relative stability of the syncline. A transient effect of this is the production of a series of coves of the Lulworth type, such as may be seen in Traeth yr Yscland, and again north of Cwm Tydi. This structure further accentuates the approximate parallelism of strike, pitch, and coast-line, though, as the map shows, it is to the slight divergence between strike and coast-line that the main interest of the cliffs is due. Space does not permit of a detailed description of the physical features of the area, but a few salient points may be mentioned.

The rocky cliffs of the coast-line fringe a district of cultivated valleys and moorland ridges, the highest ground being occupied by the gnarled series, *Triangulatus* grits, and the Upper Birkhill mudstones. Conspicuous (and similar) features are conferred on the hill-tops by the massive grits of both the Upper Bala (gnarled) and Upper Valentian (Aberystwyth) series. Most of the valleys are choked with drift, through which rejuvenated streams have cut post-Glacial channels within the limits of the original valley. Cwm Tydi presents an interesting series of terraces, and relics of a possible raised beach platform have been observed at various points. Distinct relics of the "Low Plateau" (? Pliocene platform) of North Cardiganshire are traceable.

V. Comparison with other Areas.

A rough comparison of the Llangranog development with that of other areas has been instituted in the following diagrams, Figs. 5 and 6, but it cannot be too strongly stressed that the estimation of thicknesses in the Llangranog area claims to be approximate only.

In the case of the Birkhill beds, Fig. 6 brings out the comparatively great thickness of the higher zones, and compression of the lower ones of the Llangranog district in comparison with other areas.

In several cases, minute lithological resemblances have been found. Thus the pale bands in the *persculptus* shales compare with the "Mottled Beds" of Corris and Machynlleth, and the *magnus-sedgwicki* mudstones of Llangranog recall the *communis* and *convolutus* mudstones of the Pont Erwyd district.

Note on the Gnarled Mudstone.

The peculiar character of this rock, with its included masses of strongly contorted grits, requires special consideration. The rock varies greatly in thickness within the area, and at one point (north of Penbryn) entirely disappears by attenuation. A similar rock of variable thickness occurs on the same horizon throughout Central Wales. This has been described by Dr. O. T. Jones and Professor W. J. Pugh (3, 4, 5) and is also referred to by the Misses Drew and Slater (6) and Dr. H. Lapworth (7).

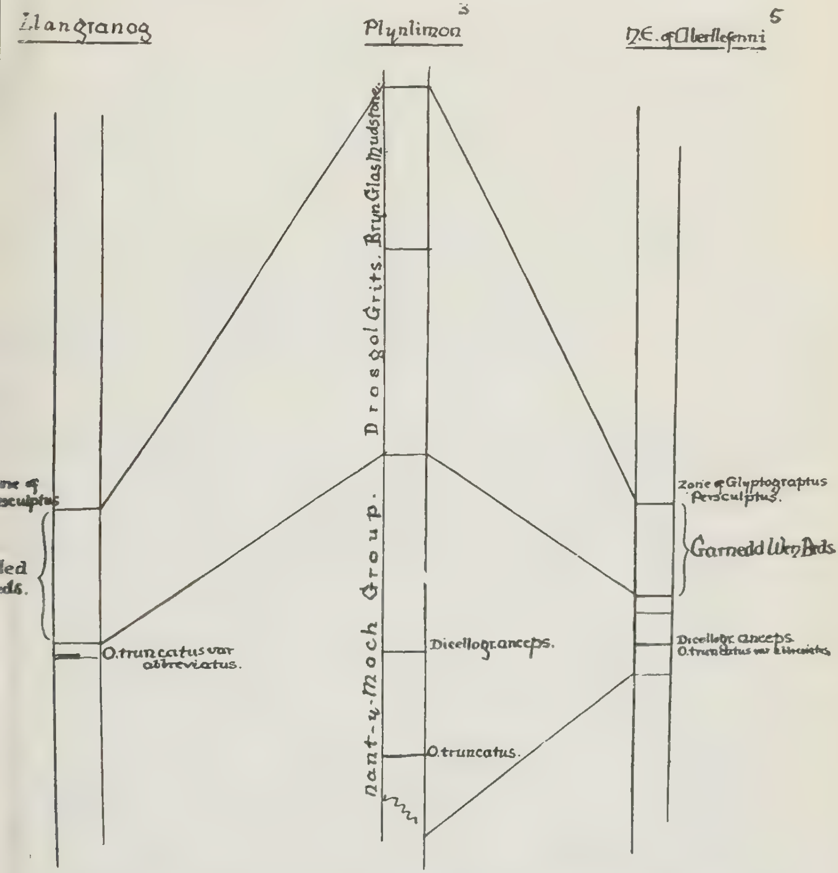

FIG. 5.—Comparative sections illustrating the relation of the Bala Sequence at Plynlimon and N.E. of Aberllefenni to that near Llangranog, on the scale of 800 feet to the inch.

In the Llangranog area, at the one spot where the base of the mudstone is visible, it rests on a band of grit entirely similar in character to the included masses of grit above, but obviously lying "in situ" (see Plate XIII, 2). The included masses themselves are apparently (but perhaps deceptively) very much contorted,

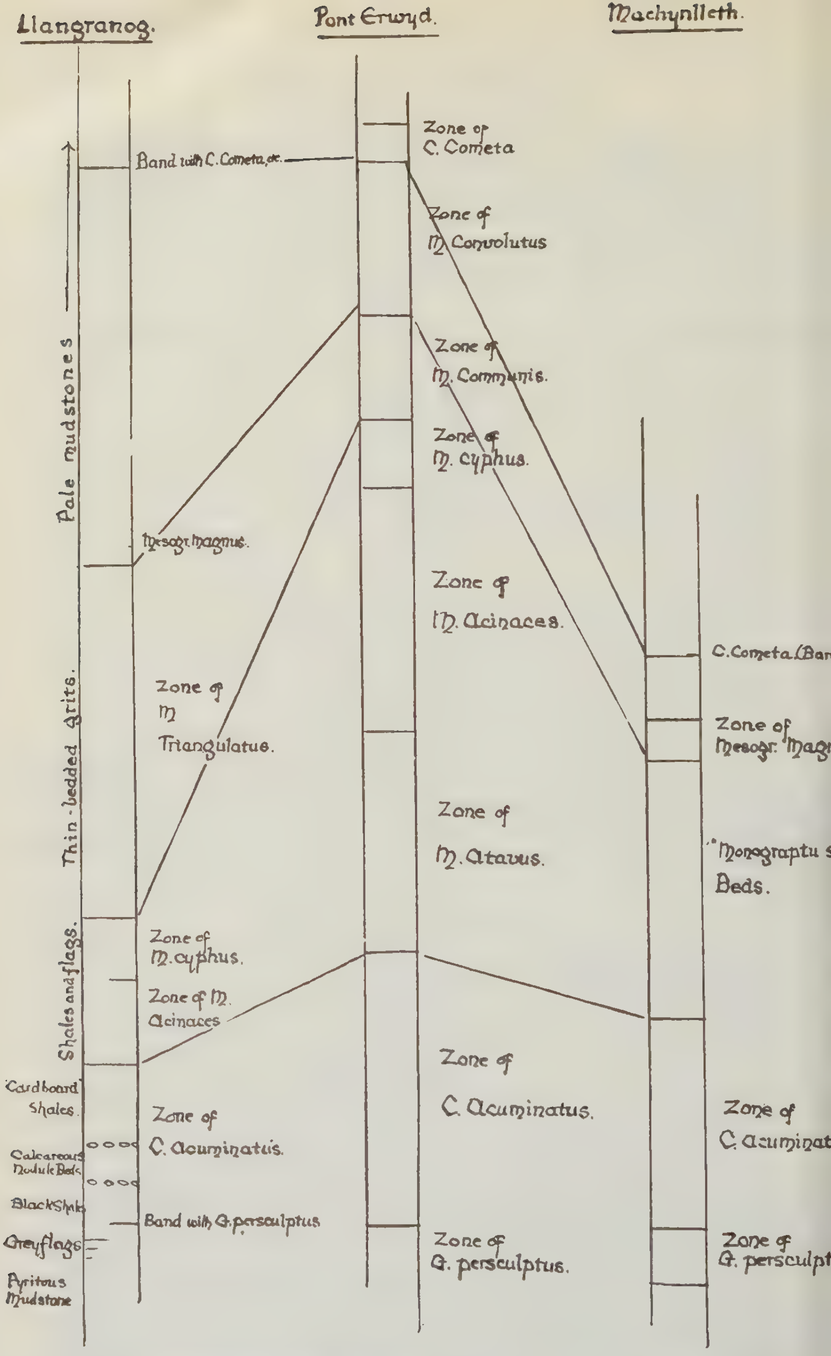

FIG. 6.—Comparative sections illustrating the approximate relations of the Silurian Succession at Llangranog, Pont Erwyd,[1] and Machynlleth,[2] on the scale of 100 feet to the inch.

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[1] Q.J.G.S., vol. lxv, 1909, p. 504, fig. 11, scale slightly increased.

presenting curious twisted shapes recalling on a larger scale those of chalk flints in some Eocene deposits, and are so utterly different in character from the surrounding mudstone that the whole structure can only be interpreted as a large scale conglomerate with "boulders" derived from the debris of the earlier formed grit.

On this supposition, the sequence of events within this area must have been as follows :—

(*a*) Deposition of the original grits.

(*b*) Period of storm conditions under which the grits were broken down and swept (though not necessarily transported far) into the focus of deposition of the mudstone which now surrounds them.

The breaking down of the grits during such an era of storm-conditions, would thus determine a break in the sequence of deposition far more serious than any which can have occurred within this area at the *G. persculptus* horizon, usually taken as the base of the Silurian succession. At this last-mentioned level, in the Llangranog area, the rocks of the "Upper Bala" series pass with entire conformity into the *G. persculptus* zone.

The physical disharmony occurring at the gnarled mudstone horizon is in agreement with the universal palaeontological break between the *D. anceps* and *G. persculptus* zones.

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(5) Professor W. J. Pugh, "The Geology of the District around Corris and Aberllefenni": *Q.J.G.S.*, vol. lxix, 1923.
(6) Misses Drew and Slater, "The Geology of the District around Llansawel": *Q.J.G.S.*, vol. lxvi, pt. 3, 1910, p. 417.
(7) Dr. H. Lapworth, *Q.J.G.S.*, vol. lvi, pt. 1, 1900, pp. 75–6 and p. 96.

Graptolites marked * determined by Dr. Jones.

REVIEWS.

Ammonites from the Upper Kimmeridge Clay. By E. Neaverson, D.Sc. Papers from the Geological Department of the University of Liverpool. pp. 1–45, pls. i–iv. 1925.

The ammonites of the Upper Kimmeridge Clay, which form the subject of Dr. Neaverson's excellently produced and well-illustrated memoir, have generally been referred to by English geologists as *Ammonites biplex*, a name that was characterized by Mr. Lamplugh thirty years ago as being "almost without determinative value". Dr. A. M. Davies, again, in 1909, stated that ammonites ascribed to this "unsatisfactory species" occurred both in the true Kimmeridge Clay and in the Hartwell Clay, now generally recognized as Portlandian.

We notice that Dr. Neaverson, who has now monographed this comprehensive *Ammonites biplex*, includes the Hartwell Clay in the Upper Kimmeridgian. Since on the Dorset coast the zone of *Pallasiceras rotundum* is some distance below the base of the sands, there may be justification for this correlation, but Dr. Neaverson goes much further when he states that there seems to be no doubt that the use of the term Portland Sands must be discontinued as far as the sandy beds below the Portland Stone Series of Dorset are concerned, because their faunal affinities are Kimmeridgian rather than Portlandian. The Dorset succession is and must remain the type-succession, and the Portland Sands were definitely referred to the Portlandian Stage already by d'Orbigny. The fact that elsewhere a clay facies might occur at a level above the top of the clay of Kimmeridge should not be allowed to influence the delimitation of these stages. Moreover, since Dr. Neaverson himself confesses that the ammonites from this horizon were practically (*sic*) unknown, we may feel sceptical even about the faunal affinities being Kimmeridgian.

The account starts off with the statement that the true *Ammonites biplex* J. Sowerby, the type of which came from the Drift of Suffolk, is of Argovian age. Unfortunately the author does not attempt to trace the relations between the (still doubtful) true *Perisphinctes* and the numerous forms that are such important faunal constituents in many Lower and Middle Kimmeridgian deposits all over the world, and the Upper Kimmeridgian *Ammonites biplex*. The three series of ammonites recognized by Dr. Neaverson in his lowest (*wheatleyensis*) zone and their successive offshoots thus appear to have been named with insufficient knowledge of contemporaneous faunas of other areas ; and there is no reference even to recent work on certain Volgian faunas. The careful descriptions, however, as well as the good illustrations ought to enable geologists to name some of their Upper Kimmeridge Clay ammonites, even if they question the value of the author's generic divisions and conclude from Mr. Buckman's opposition that the sequence itself (discussed by Dr. Neaverson in the GEOLOGICAL MAGAZINE, 1924, pp. 145–51) is as yet somewhat uncertain.

AUSLÄNDISCHE SYSTEMATIK, KLASSIFIKATION, UND NOMENKLATUR DER MAGMENGESTEINE, I. By K. H. SCHEUMANN. Fortschritte der Min. Krist. und Petrographic. Bd. x, 1925, pp. 187–310.

THIS is a long review devoted to the growth and development of systematic igneous petrography since 1900, as revealed in extra-German literature, with special reference to British and American contributions. In their turn the quantitative chemical and mineralogical classifications are reviewed, and short accounts are given of the various qualitative systems proposed. An extensive bibliography of literature is included, and gives indication that the author has spared no pains in becoming acquainted with foreign writings, though it is clear that access to much of the recent literature is still a difficult matter for German petrographers.

The review concludes with a section on igneous rock nomenclature and a catalogue of 360 rock names, including a large number of the new types described since 1900, as well as varietal types, and those unfortunates on the definition of which the literature reveals no consensus of opinion. It is this section of the paper which is of most interest to British and American petrographers.

Scheumann's list is confessedly incomplete, as it is largely confined to those names which have found their way into English petrographical literature. With Scheumann's list as a basis, the writer has made a rough estimate of the new terms coined since 1890 (qualified terms excluded). During the period 1890–9 the number of new names introduced approximated to ninety. It was at the close of this fruitful decade that protests were lodged by Van Hise and Hobbs against the multiplicity of rock names, and the advantages of a nomenclature on the lines of organic chemistry pointed out by the former. But these were voices crying in the wilderness, as the succeeding quarter of a century now testifies, for we find that during this period name-coining has shown no wane. A record of approximately 260 represents the spoil of these years, and it is not without interest to observe the chief national contributions. According to authors, U.S. America-Canada lead with 81, France 42, Fennoscandia 33, Britain 28, Germany-Austria 27. The high number credited to America and the comparatively low numbers for Britain and Germany-Austria, are doubtless in large measure to be attributed to the influence of quantitative classifications on the one hand, and on the other to the dominant position of the more accommodating Rosenbusch system. History repeats itself. Near the close of this period (1923) protests were once more raised, and it is not without significance that these should emanate from the chief American coiner, " who knows the fatal facility with which a new name slips from one's pen . . ." *Auspicium melioris aevi.* Through the years Norway and Madagascar vie with one another in the keen race for the laurels of petrographic cacophony. Time was when metamorphic petrography was threatened with a similar place-name nomenclature, as in Salomon's *astite, aviolite, edolite,* etc., or the weird introductions of Kinahan, as *metapepsis* and *paroptesis.* Happily the danger period was safely weathered, and to-day calm waters lie ahead. Surely none but a rabid systematist can view with equanimity the ever-swelling riot of *anabohitsite, espichellite, katzenbuckelite, kauaiite, nosykombite, onkilonite, topsailite, tsingtauite,* and like monstrosities ? At the present stage one may well ponder where and what is the end ? Clearly the advice of provincial, or even international, committees is to little purpose, as witness the scant attention paid to the deliberations of these august bodies.

Time and the progress of physico-chemical petrology will order their destiny. Is it an unkind hope that many of them may suffer the fate of their metamorphic brethren, banished to join the obsolescent throng of *besimaudite, catawberite, floitite, metapepsis,* and their kind ?

C. E. T.

ON THICKNESS VARIATIONS IN THE LOWER COAL MEASURES OF EAST GLAMORGANSHIRE AND MONMOUTHSHIRE. By R. DAVIS and A. H. COX. Proc. South Wales Inst. Eng., vol. xxxviii, 1922, pp. 41–62.

SOME EFFECTS OF INTRA-COAL MEASURE MOVEMENTS. By R. DAVIES. Ibid., pp. 611–622.

A GROUP OF RED MEASURES OR " COLOURED STRATA " IN THE EAST GLAMORGAN AND MONMOUTHSHIRE COALFIELDS. By A. HOWELL and A. H. COX. Ibid., vol. xl, 1924, pp. 139–174.

IT is contrary to our usual custom to notice papers appearing in other British journals, but an exception is made in favour of the group of memoirs listed above, because they contain matter of general interest and probably few geologists commonly see this particular periodical. The first two papers show by means of a detailed study of local thicknesses in the " Lower Coal Measures " (in the local sense) of the area named, i.e., in the beds just below the Pennant Series, the occurrence of two sets of tectonic disturbances during their deposition, one about a set of N.W.–S.E. axes, the other being a forerunner of the later E.–W. folds.

The third paper gives an account of an area of Red Measures, the Deri Beds, consisting largely of red and purple marls, which are correlated with the Etruria and Ruabon Marls of other areas. They are only found over about 130 square miles, and the occurrence of this local patch of " red " rocks surrounded by more normal types in continuity with them offers an interesting problem in sedimentary petrology.

REPORTS AND PROCEEDINGS.

MINERALOGICAL SOCIETY.

19*th January*, 1926.

Dr. C. E. Tilley: Some Mineralogical Transformations in Crystalline Schists.

Attention is devoted to the pelite isochemical rock series with special reference to the mode of origin of the index minerals biotite, almandine, staurolite, etc., in crystalline schists. A fuller recognition of the element of progression in metamorphism brings inevitably in its train this genetic problem, hitherto greatly neglected. Mineral and rock analyses are graphically represented in triangular plots. Examination shows that the mechanism of the mineralogical transformations is something much more complex than is explained away by the customary simple equations. Further insight into the prevailing reactions depends very largely on a closer chemical investigation of the common metamorphic minerals occurring in the groundmass of the crystalline schists.

Dr. A. Brammall: Primary Gold and Silver in the Dartmoor Granite.

Occurrences of minute flakes of native gold in the normal grey biotite-granite were described and specimens were exhibited. The occurrences were shown to be independent of quartz-veins, tourmaline-veins, and zones affected by pneumatolysis, and flakes occur as inclusions in felspar and quartz. A suite of assays of apparently barren tor- and quarry-granites, graphic granite, pegmatites, and vein pyrites shows that both gold and silver are widely distributed throughout the granite, the values ranging from 1–10 grains of gold and 1–161 grains of silver to the ton. A sample of biotite yielded 108 grains of silver to the ton. Both metals are undoubtedly primary.

A. F. Hallimond: On the Chemical Classification of the Mica Group: II. The Basic Micas.

In continuation of previous work on muscovite, the analyses of biotite and phlogopite are recalculated in molecular proportions, SiO_2 being made equal to 600. The ratio of potash is approximately constant, as in the acid micas. Values for the R_2O_3 and RO groups are plotted in a diagram which makes it possible to compare any new analysis with existing data. On this diagram biotite and phlogopite form a continuous series, covering a very well-defined area and separated from muscovite by a wide interval. The representation of alumina in the form of basic groups, AlO, etc., leads to the classification of the micas in a range of increasing acidity from muscovite to phlogopite. This arrangement corresponds generally with the gradation in acidity of the rocks from which the respective micas were derived. The micas can be represented either by hexasilicic or trisilicic formulae; evidence from certain phlogopites somewhat favours the latter type.

G. Greenwood: The Construction and Use of an X-ray Goniometer. Crystal-structure of Glyoxaline Compounds.

A new form of X-ray spectrometer has been constructed. It embodies the principles of the optical goniometer. The crystal is mounted on a goniometer head rotating about an upper scale, and the adjustments are made optically by means of a telescope and collimator. In using the apparatus, a source of X-rays is used instead of a source of light and an ionization chamber, instead of a telescope. The ionization chamber rotates round a second scale, concentric with the upper crystal scale. Small and transparent crystals are usually used and it is then possible to measure the crystallographic angles, i.e. angles between crystal faces or lattice planes of the structure, and in this way to make the ordinary angle measurements even when the faces are not actually present. It is also possible to measure glancing angles and spacings, and thus to make determinations of the space-group to which the crystalline structure belongs. Two substances were investigated: (*a*) glyoxaline-4-sulphonic acid. The space group was determined and the crystal class — previously determined from the alternating presence of minute faces—was confirmed. (*b*) Glyoxaline. This substance does not form complete crystals. It was possible to measure crystal angles, and deduce the axial ratios, etc. The symmetry is monoclinic.

OBITUARY.

Mr. R. B. Newton, I.S.O., F.G.S.

Richard Bullen Newton, for many years an extensive contributor to the literature of invertebrate palaeontology, died on the 23rd January at the age of 71. His early training was on the palaeontological staff of the Geological Survey, but in 1880 he was transferred to the Geological Department of the British Museum to help in the removal of the collections and their rearrangement at the new Natural History Museum at South Kensington. There he continued an active worker until shortly before his death, although officially retiring in 1920.

His numerous papers, reports on collections sent to the Museum, have dealt chiefly with Cretaceous and Tertiary Mollusca, and with the larger Tertiary Foraminifera. In addition to their purely palaeontological interest, they have contributed considerably to our knowledge of the stratigraphy of many distant regions, especially Africa and the East. They include his " Systematic List of the F. E. Edwards Collection of British Oligocene and Eocene Mollusca " (1891), " Cretaceous Gastropods and Pelecypoda from Zululand " (1909), " Conchological Features of the Lenham Sandstones of Kent " (1916), and " Eocene Mollusca from Nigeria " (1922).

He was awarded the Wollaston Fund of the Geological Society in 1914, was President of the Malacological Society, 1910–12, and of the Conchological Society, 1913–15. On his retirement in 1920, the Imperial Service Order was conferred upon him in recognition of his long period of service.

His work has always been characterized by its extreme accuracy, and, in view of his very wide knowledge of fossils and of palaeontological literature, his loss will be greatly felt by all his colleagues.

L. R. C.